Sabbatical Report

Fall 2007 - Spring 2008

By

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Department of Philosophy

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Sabbatical Project

Submitted by Dr. Andrea Grace Diem, Philosophy

Project to be completed during the 2007-2008 school year

TWO MONOGRAPHS

Evolutionary Philosophy: An Introduction

Einstein vs. Bohr: The Great Physics Debate of the 20th Century

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OBJECTIVE:

1. During the Fall semester I will complete my reading and research on how Darwinian evolution has impacted current philosophical thinking and write a 40 to 60 page monograph which summarizes my findings.

2. During the Winter/Spring semester I will complete my reading and research on the famous debate between Albert Einstein and Niels Bohr on the implications of quantum theory on philosophy, which will eventually be outlined in a 40 to 60 page monograph I will write.

   Both monographs will be published on their own distinct websites and will be available for free to anyone. Print editions will also be made on a per request basis.

WHO WILL BENEFIT FROM THIS PROJECT? [Students, Faculty, and the College]

The Students: With the ever increasing prices of textbooks I think it is important, especially in light of the internet, to be able to provide unique texts on leading edge ideas in philosophy and science. These monographs will be online for free (with appropriate hypertext links to other resources on the web), and thus can serve as essential guides to students. Students will also be able to access fairly complicated ideas more easily given the introductory style of these texts.

The Sociology and Philosophy Department: Colleagues in my department will also be able to use these two monographs in their courses as well. They can use the whole text or even select out those parts that are most useful for their course objectives.

The College: I think it is important that the college and community at large benefit from sabbatical projects. And by placing these two monographs on their own unique websites it will allow anyone within the college, within the community, and within the world at large to have direct access to this vital information. My website already receives a large number of visits from others outside of Mt. San Antonio College and I know that having these two new resources will be a welcome addition to those viewers.

HOW THE PROJECT WILL BE ACCOMPLISHED AND RATIONALE

I have selected twenty seminal books on the subject (10 for evolutionary philosophy; 10 for the Einstein-Bohr debate) and plan on reading them systematically during the sabbatical year. I will also be doing web based research to augment my reading.

After I have completed the necessary reading and research for each monograph, I will write the text and then place it on its own unique website. I have given myself four and half months for each text.

WEEK BY WEEK SCHEDULE (tentative)

August 28th to September 31: READING AND RESEARCH

EVOLUTIONARY PHILOSOPHY

Chosen texts to read during this period:

1. *The Ancestor's Tale* by Richard Dawkins

2. *Darwin's Dangerous Idea* by Daniel Dennnett

3. *The Human Genome Sourcebook* by Tara Acharya and Neeraja Sankaran

4. *Why Darwin Matters* by Michael Shermer

5. *DNA* by James Watson

October 1 to November 30th : READING AND RESEARCH

Chosen texts to read during this period:

6. *Nature Revealed* by Edward O. Wilson

7. *Challenging Nature* by Lee M. Silver

8. *The Reluctant Mr. Darwin* by David Quammen

9. *The Making of the Fittest* by Sean B. Carroll

10. *Darwin Loves You* by George Levine

December to December 22: WRITING THE MONOGRAPH

Writing and creating website

Finishing first text

EINSTEIN vs. BOHR

Chosen texts to read during this period:

1. *Subtle is the Lord: A Biography of Einstein* by Abraham Pais

2. *Suspended in Language* (edited volume)

3. *Niels Bohr's Times: A Biography* by Abraham Pais

4. *The Universe in a Nutshell* by Stephen Hawking

February 26 to March 31st : READING AND RESEARCH

Chosen texts to read during this period:

5. *A Short History of Nearly Everything* by Bill Bryson

6. *Erwin Schrodinger: A Life* by James Moore

7. *The End of the Certain World* by Nancy Greenspan

READING AND RESEARCH

Chosen texts to read during this period:

8. *Einstein's Moon* by F. David Peat

9. *Speakable and Unspeakable in Quantum Mechanics* by J.S. Bell

10. *Einstein, Bohr, and the Quantum Dilemma* by Andrew Whitaker

April 1 to April 30: WRITING THE MONOGRAPH

Writing and creating website

May 1 to June 15: WRITING THE MONOGRAPH

Writing and creating website

Finished second text

COPYRIGHT ISSUES:

The copyright to my two monographs will be assigned to Mt. San Antonio College.

Statement of Purpose:

During the sabbatical year I accomplished three main tasks:

- The writing of two monographs for my philosophy course;
- The development of Web pages where these material can be located;
- And the reading of over twenty books relevant for the research of the monographs (annotation of most of these works are included in the monographs).

Monographs:

The primary object of the sabbatical project was to write two monographs for philosophy. The topics included:

- A general introduction to evolution and philosophy, which I call evolutionary philosophy; I explain both how evolution works and then focus on how evolution accounts for human consciousness.

- The second monograph offers a brief introduction to quantum physics and then proceeds to illustrate the debate between Albert Einstein and Niels Bohr over quantum physics and whether it paints a determinate world or an indeterminate one. The philosophical implication of this debate was the cornerstone for this text.

The monographs are entitled:

- *Darwin's DNA: A Brief Introduction to Evolutionary Philosophy*
- *Spooky Physics: Einstein vs. Bohr*

Webpage Development:

To make the writings available to my students and others for free I developed a Web page for each. Students can access the Web page and from there open up an easy to read pdf file. If one wishes to have hard copies of the texts they are available on the internet and are sold at cost without profit. Mt. San Antonio College owns the copy right for each of them and this is indicated on the front page of each monograph.

The Web page addresses are:

For *Spooky Physics*:

http://spookyphysics.com (domain name was purchased) or

http://elearn.mtsac.edu/adiem/sab.htm

For *Darwin's DNA*:

http://darwinsdna.com (domain name was purchased) or

http://elearn.mtsac.edu/adiem/sab.htm

Readings, Research Design and Methods of Investigation:

For this sabbatical project, in addition to writing two monographs on science and philosophy, I read more than ten books in the area of physics, specifically quantum physics, and more than ten books in the area of evolutionary biology. Some of the reading dealt with the science involved and some focused on the biography of a renowned scientist, including Albert Einstein, Charles Darwin, Niels Bohr, and Max Born. These twenty plus books served invaluable to me in writing the two monographs.

As I completed the readings I wrote up annotations for most of them and including the annotated readings near the end of each of the books. At first my annotations were hand written in paper notebooks but eventually I moved to inputting the key ideas directly into files on my laptop. This saved time and was altogether a better method.

Some of the longer readings, such as Richard Dawkins' *Ancestor Tale* and Daniel Dennett's *Darwin's Dangerous Ideas*, took an entire month to complete in full and to digest. Yet, these readings offered so much depth to the topic at hand that I believe that I could not produce the work that I did without them.

Furthermore, when writing the actual two books I utilized science journals such as *New Scientist* and *Seed*. The numerous materials on the internet also proved essential in garnering ideas and finding important supporting quotes.

Personal Journal of Sabbatical Activities:

From late August 2007 to late November 2007 I read the ten books on evolution. I enjoyed these readings so much that I found myself visiting Barnes & Nobles purchasing and reading additional books on the topic, even ones not included on sabbatical list of books. For instance, *Dawkins Vs. Gould: Survival of the Fittest* by Kim Stefelny comparing Stephen Jay Gould with Richard Dawkins was a great read and furthered my knowledge in this field.

Then the following month up until January 2008 I wrote the book on the topic of evolutionary philosophy, which I entitled *Darwin's DNA: A Brief Introduction to Evolutionary Philosophy.* Having read so much on the topic of evolution and having a background in the study of consciousness the ideas flowed quite easily. I decided to write up the report in three sections:

The first section explained what evolution is and, more importantly, the major evidence we have for it. Part two of the book looks at how what is called the "mystery of consciousness," to quote John Searle, can be understood via evolution. My thesis here is that human consciousness in part arose as a visual simulator; it allows our species to play out a variety of scenarios, whether it be the lion coming in for the kill or snake hissing a threat to us. Because we can imagine different scenarios we can play out in our heads how to respond and thus we can more easily survive a variety of situations when actually confronted with them. The third section includes my annotations on the sabbatical readings (this was not a required part of the project but an addition); these annotations make up a large part of the book. And the final section is an appendix, copy right free, written by Charles Darwin on the "Descent of Man."

I really enjoyed designing the book cover for this work. I found a copy right free image of a DNA molecule and added a few creative features to it. The title was either going to be *Plato's DNA, Adam's DNA*, or *Darwin's DNA* and the latter won.

Having completed my winter online courses in January and part of February 2008, I commenced my research on physics and philosophy. Specifically, I concentrated on Albert Einstein and Niels Bohr and the notorious debate they held on the determinacy or indeterminacy of quantum physics. Once the books on the subject were read and annotated by early May, I spent the last six weeks of the sabbatical year, up until middle June, writing *Spooky Physics: Einstein vs. Bohr.* When colleagues hear the title of this work I inevitably get asked, "Well, who won?" My response, as written in the conclusion of the book, is that "the answer to that question is as indeterminate as the position of a single photon." In other words, the debate is still unresolved. The goal in writing this book was not so much to answer the question but to highlight the key positions of each physicist and the philosophical implications of them.

This monograph was written in four chapters and it included an introduction to the topic of quantum mechanics and a conclusion addressing who, if any, won the debate. Chapter one explained quantum weirdness; chapter two highlighted Einstein's position on the topic; chapter three defined Bohr's stance; and the actual debate between the two scientists was covered in chapter four.

When developing the book cover for this piece, again I found a copy right free image, but this time with the theme of quantum physics. The book title plays off Einstein's "spooking action at a distance" where twin particles separated by great distances experience simultaneous occurrences.

By middle June both of these books were published online and made available to students for free via a pdf file with Mt. San Antonio College owning the copy right to each of them. If anyone wishes to purchase the hard copy of the books they will be sold over the internet and for no profit.

Value to the College

This semester (Fall 2008) I have already incorporated the materials of my sabbatical project into my philosophy courses; both monographs are required reading. Students seem greatly to appreciate the access to free writings on the internet. Moreover, reading writings by the professor somehow seems to enhance their interest in the subject. Philosophy of science is an area I cover in my Introduction to Philosophy courses and so having materials on both evolution and its connection to consciousness and on quantum physics and its connection to indeterminism will prove invaluable to me.

The monographs, along with the annotated readings I completed during the sabbatical year, are not only available to the students on the Web but also to my colleagues. They too can utilize the monographs for their classes, or if interested in one of the books I annotated they can access a summary of it on the internet.

Not only is there a benefit to the student body and to the Department of Philosophy at Mt. San Antonio College but I would argue that this project serves as a benefit to the college in general. Independent research and writing not only can enhance the quality of education the students receive but can also add to the reputation of the department and the educational institution itself.

The monograph on evolutionary philosophy, *Darwin's DNA*, was picked up by a website, called Integral World Network, which concentrates on studying consciousness. It has over 300,000 viewers per year. The following are the addresses to the site with my work posted:

http://www.integralworld.net/diem-lane1.htmll

http://www.integralworld.net/diem-lane2.htmll

http://www.integralworld.net/diem-lane3.html

Taking my work beyond the classroom to the world at large has been very rewarding.

Final Note:

Overall, I feel that the sabbatical project was a great success. From my perspective I enjoyed the books I read and I loved the opportunity to produce monographs and develop Web pages which contain content rich material for my courses.

I would like to thank Mt. San Antonio College and the sabbatical committee for giving me the wonderful opportunity to pursue these interests.

The following are the two monographs and their respective annotated bibliographies:

Monograph 1

DARWIN'S DNA:

A Brief Introduction to Evolutionary Philosophy

Darwin's DNA

A Brief Introduction to Evolutionary Philosophy

ANDREA DIEM-LANE

Darwin's DNA

First Edition

ISBN 1-56543-100-6

10 9 8 7 6 5 4 3 2

Mt. San Antonio College, *Walnut*

Printed in the United States of America

To my husband, David

Table of Contents

Part One: **Explaining Evolution**

One of the difficulties in explaining the theory of evolution is where to start. I have noticed over the years in teaching this subject at the undergraduate level that most students don't really know much about Charles Darwin and they certainly know less about the mechanism of natural selection. Usually, I have a fairly vocal contingent of fundamentalist Christians who tend to believe in the literal interpretation of Genesis and therefore believe that God created the world in six days. Some accept an old earth hypothesis (five billion years old); whereas others believe that the world is only several thousand years old.

Given this mixture in my class, my husband, David, who is also a Professor of Philosophy, suggested a way that not only reaches students of varying persuasions but ends up actually convincing them, even if only partially, of the viability of evolutionary theory.

Whenever you have to present a controversial idea, he has noticed it is best to begin with what we all know and what we all agree upon. Thus, he advised that I ask for a student volunteer and use him or her as my example.

Let's imagine that the young man's name is Shaun. He is 18 years old. The first question we pose is a simple one. Why does Shaun physically look the way he does? Excepting his clothes and hygiene and other personal choices, my students invariably say "because of his parents."

And that is certainly true and nobody tends to dispute the fact that his parents were the key to his physical looks. But what is it that his parents bring to the equation? The simple answer, of course, is that Shaun's father (let's call him Christopher) contributes sperm whereas his mother (let's call her Catherine) an egg. Both substances are quite small. A human sperm for instance (including both its head and its tail) is roughly 55 microns, so tiny that it is 25,000 times smaller than a golf ball. At this point, we start to see one of the first hallmarks of science and one that is often misunderstood: *reductionism*. The contribution that Shaun's parents made to their offspring doesn't come at the phenotype level (that is merely the replicating appliance), but rather at the genotype particulate. We have scaled down from a 6"1 body and a 5"4 body to precisely what those larger frames house—a sperm and an egg. Now we have literally "reduced" Shaun's parents to the arena where the information they share is more easily accessible and localized.

One metaphorical way of putting this is to imagine that Christopher and Catherine are individual books, filled with all sorts of historical information. Their desire is to recombine their books and produce a new edition. Since human sexual intercourse is literally the intertwining of two fairly large body forms so that a transmission of information can catalytically induce a viable recombination to occur, we can readily see that what makes a child is essentially the intersecting of binary forms of data.

The larger question that arises in this metaphor (with its real world applications) is how to decipher Catherine's and Christopher's contributions to the book they named Shaun. In what language are their books written? Are they the same language or different? What is the alphabet or rudimentary notation wherein their respective knowledge is inscribed?

Today, unlike in Darwin's day, we can actually answer these queries with remarkable accuracy. Although an egg and a sperm are compositely varied, the essential code they contain is written in a biological language known most famously by its initials: D.N.A. or more properly deoxyribonucleic acid. This language comes in four letters, easily remembered with the acronym C.T.A.G. Here "c" stands for cytosine, "t" for thymine, "a" for adenine, and "g" for guanine.

Thus, Catherine and Christopher shared books which had a common four lettered language. These letters further comprised whole pages numbering in the tens of thousands known as genes which formed twenty-three chapters known as chromosomes. Our entire book is known as a genome.

Shaun is, therefore, the result of two genomes (books) recombined which results in a unified outcome of 25,000 plus genes (pages), 23 chromosomes (chapters), all written in DNA (a four letter alphabet).

Sexual selection, however, is merely the start of why Shaun looks the way he does. Since obviously his mother could have chosen another author to help write her memoirs and in so doing produce a completely different son with a unique set of genes. Shaun isn't merely a duplicate reconfiguring of his parent's deoxyribonucleic acid. Occasionally, when DNA is copied throughout one's body it makes a copying error, what is known as a mutation. This can simply be a one letter change. Instead of ATGGTTTGATGTC, one might get ATGGTTGATTGTC. While at the level of just script it looks somewhat inconsequential, but in terms of applied genetics such minor variations can loom large.

Why mutations occur is a deep subject, but not an insurmountable one, especially if you have an understanding of Heisenberg's uncertainty principle and how quantum mechanics is based on indeterminacy. The introduction of "chance" (or occasional mutations) into the genome is important because it causally explains how a child can indeed be unexpectedly and unpredictably different than his parents. In other words, sexual selection is just one component in what makes up Shaun's physical characteristics. DNA mutations are another. There are two fundamental ways to mutate a gene. The first way is through environmental damage. As the *Learn Genetics* website, sponsored by Genetic Science Learning Center at the University of Utah, explains:

Ultraviolet light, nuclear radiation, and certain chemicals can damage DNA by altering nucleotide bases so that they look like other nucleotide bases.

When the DNA strands are separated and copied, the altered base will pair with an incorrect base and cause a mutation. In the example below a "modified" G now pairs with T, instead of forming a normal pair with C.

Environmental agents such as nuclear radiation can damage DNA by breaking the bonds between oxygen (O) and phosphate groups (P).

Cells with broken DNA will attempt to fix the broken ends by joining these free ends to other pieces of DNA within the cell. This creates a type of mutation called "translocation." If a translocation breakpoint occurs within or near a gene, that gene's function may be affected.

The second way is by DNA replication. As the same website elaborates:

Prior to cell division, each cell must duplicate its entire DNA sequence. This process is called DNA replication.

DNA replication begins when a protein called DNA helicase separates the DNA molecule into two strands.

Next, a protein called DNA polymerase copies each strand of DNA to create two double-stranded DNA molecules

Mutations result when the DNA polymerase makes a mistake, which happens about once every 100,000,000 bases.

Actually, the number of mistakes that remain incorporated into the DNA is even lower than this because cells contain special DNA repair proteins that fix many of the mistakes in the DNA that are caused by mutagens. The repair proteins see which nucleotides are paired incorrectly, and then change the wrong base to the right one.

At this junction, most of the class is still with me, since they can readily concede that sexual selection and chance play a huge role in producing children. What is not so apparent is how a four lettered language could produce the wide array of complexity that we see in the human species. In other words, how can such diversity arise from only four varying molecule clusters?

To explain it better, I start again with what we know and then posit a query. The English language has 26 letters and from that can we get a wide diversity of published materials? The answer is an easy yes. Just go to the local library and you can see what diversity such a language can bring—ranging from Cosmopolitan magazine to US weekly to the New York Review of Books to Surfer's Journal. All telling different stories, yet all written in the same English alphabet utilizing A's to Z's. But what would happen if we only had 2 letters, not 26; could we still have the same wide diversity? Usually, at this moment, my students shake their heads with a face of disapproval, wrongly imagining that more letters would mean greater diversity.

Such is not the case, however. If we only had two letters or two numbers (0 and 1), we could, in point of fact, reproduce our entire alphabet and our entire English set of words, sentences, paragraphs, and books. Indeed, we could recapitulate any system of information that has appeared on earth. The very basis of computer programming is predicated upon a string of 0's and

1's. The internet itself can be seen as a huge ocean of cascading binary bits, triggering off an electron dance near the speed of light where information reaches innumerable portals.

The mythic universal library, so hauntingly brought to life in Jorge Borges' famous short story, "The Library of Babel," which was written before the advent of the World Wide Web, indicates an almost infinite range of information. W.V. Quine, the late professor of philosophy at Harvard University, ironically pointed out that letters were actually unnecessary, since even a dot and a dash could suffice and all the texts of the world could be replicated by such a simple binary. As Quine summarizes, "The ultimate absurdity is now staring us in the face: a universal library of two volumes, one containing a single dot and the other a dash. Persistent repetition and alternation of the two is sufficient, we well know, for spelling out any and every truth. The miracle of the finite but universal library is a mere inflation of the miracle of binary notation: everything worth saying, and everything else as well, can be said with two characters. It is a letdown befitting the Wizard of Oz, but it has been a boon to computers."

Even here, one could argue that Quine didn't go far enough, since all one would need is a dot and its absence. The dash itself being unnecessary since a thing and its absence is sufficient to be its own binary system.

Thus, it comes as a surprise to my students to realize how easy it is to get such wide diversity from a simple language or code. But even though sexual selection and genetic mutations can explain much, they are not sufficient to explain a much larger process called natural selection, for which Charles Darwin is rightly famous.

Natural selection, as defined by Darwin in his famous *On Origin of Species*, is:

Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection. We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of Nature. But Natural Selection, as we shall hereafter see, is a power incessantly ready for action, and is as immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art.

Natural selection, though precisely defined by Darwin, has led to some unnecessary confusion since it mistakenly implies a conscious act on the part of nature to pick and choose. Rather, it may be more properly understood as *natural elimination* and anything that can survive that global and unending process is, because of such survival, sufficient (not necessarily "best") to continue on. Viewed in this purview, evolution by natural selection isn't so much about "fittest" or "strongest" or "best," but rather as contingently successful. With the operative word here being contingent since what is viable in one environmental niche may not be so in another.

What cannot be denied are the vast odds against life to survive under such harried conditions. That anything does survive tells us much about both the environment from where it arose and the competition it had to go head to head against in order to live long enough to pass on its code. Natural selection or natural elimination or survival of the sufficient (however, we describe this winnowing process) is fundamentally a description of how organic life struggles for a temporary respite from ultimate annihilation. We can witness this struggle right now in the world we live in. We hear of an earthquake in China, where thousands are summarily killed, and yet several individuals, defying astronomical odds, survive. We hear of powerful and relatively new viruses, such as HIV, which can kill millions after years of incubation. And, yet, there are a few who seem to ward off its terminal sentence and live relatively long and healthy lives, even without the introduction of new drugs.

How is this possible? Variation. Natural selection only works if there are variations among organic life, where a panoply of potential body types live and die. Those that do survive this gauntlet (and the gauntlet, lest we forget, is unending), do so only temporarily and only under certain conditions. It is under this severe testing that we can start to see how certain adaptations are better suited than others. Further, if those adaptations can produce viable offspring that carry on such favorable traits then they will have a built-in advantage over competitors that do not. This isn't a static sort of testing, however, since environments change over time and new adaptations due to wide variability arise and compete anew.

As Darwin so beautifully summarized nearly 150 years ago:

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Now going back to Shaun, we have realized three key factors which have determined why he looks the way he does: sexual selection, genetic mutation, and natural selection. Play this out in your own life. Right now you are being tested by nature, even if completely unknowingly. Either you are going to have offspring that carry on your unique DNA configuration or you are not. If the former, you are in competition with other likeminded brethren in pursuing a potential mate. If the latter, you have basically given a Trumanesque-like gesture to millions of years of competitive successes that led up to your very being. You have said, "The buck stops here." And, barring some future resurrection of your DNA in unseen ways, the book that was you will go into the non-circulating library of forgotten achievers.

But sexual success, while necessary, doesn't insure lineal success, since as we have pointed out a random genetic mutation could mean that your child won't live long enough to procreate. And, even if your child does live long enough there are many other factors to consider, including new environmental conditions (such as global warming), new strains of virulent bacteria and viruses, and any host of unpredictable variables that may arise in the unforeseen future—all of which can wipe out even the most successful of genetic programs.

All of this competition has led to a natural "editing" of what we see today. If something survives, you know a priori it has been edited or pruned by the very competition which led to its surviv-al. *Knowing the conditions from where we originally arose is a central key to understanding why we survive as we do in the present.*

Shaun, therefore, is in the most literal sense a genome with a long history, one which was shaped by factors which we cannot access fully today, but which nevertheless give hints of its long sojourn on terra firma.

Every strand of DNA contains a unique history of its journey and what must have transpired to shape it into its present incarnation. Thus, Shaun's history doesn't start with parents, or with his grandparents, or with great grandparents, but rather goes thousands, nay millions, of years back in time.

It is right here in the lecture when I ask Shaun about his ancestry. Where were you born? Where are your parents from? Where did your ancestors come from?

Nobody is indigenous to America. We all came from somewhere else. In Shaun's case, we found out that he could trace his family lineage back to Ireland and Germany. But that also is not the final resting place for his DNA. We now know that all human beings living today trace their genetic history some 90,000 plus years back to the heartland of Africa. Shaun is in this sense (as we all are) African-American, even if his latter day sojourn may have resting places in European countries. As the entry on human migration in the *MSN Encarta* puts it:

Early humans first migrated out of Africa into Asia probably between 2 million and 1.7 million years ago. They entered Europe somewhat later, generally within the past 1 million years. Species of modern humans populated many parts of the world much later. For instance, people first came to Australia probably within the past 60,000 years, and to the Americas within the past 35,000 years. The beginnings of agriculture and the rise of the first civilizations occurred within the past 10,000 years.

Shaun is literally a f…ing success. Nobody in his genetic past screwed up (pun intended). At each stage where it counted most, Shaun's elemental sequences survived and not once was there a premature extinction or death. If so, he wouldn't be here today. If so, none of us would be alive today. The very fact that you are reading this book can be taken prima facie that you are one of the great success stories in human history, indeed in all of organic history. You have won nature's lottery. . . at least so far.

Imagine how many strands of DNA never made it. Imagine how many countless sperms and eggs never reached fruition. Imagine how many life forms lived and then died before they could transmit their genetic code? Imagine the odds against you and it becomes readily apparent that the very fact you have beat such odds is a clear indication that your unique genome has some fundamental traits that have led to such success. Those traits are called adaptations. Whether you like it or not, you must be sufficiently adapted to your present circumstance or you wouldn't have been able to arrive here.

You are one of the winners.

Given this amazing history and your amazing plasticity to survive nature's twists and turns, the real question that arises is not why but how? What is it about you that has led to you? In other words, you are a distinguished survivor. And how is it that you survived this competition and others did not? Or, more generally, what traits do Homo sapiens possess that has allowed them to last this long?

But before we probe further into that question, another one still begs to be answered. How far back does our genetic code go? Almost all fundamentalist Christians, who believe in a literal interpretation of the Bible, more or less accept evolution by natural selection within a range.

What most of them object to in class is the idea that the human species evolved from some earlier primate species. As one bright Christian argued, "Yes, I can accept micro-evolution, varying adaptations and changes within a species, but what I cannot accept (and which would go against my beliefs) is the idea that one species mutated or evolved into another. I see no evidence of such a thing in the fossil record. Where are all the transitional forms? Human beings are unique."

To tackle this issue head-on in class and to answer the good questions put forth by my student, I first point out what is not so obvious at first. All of evolution, at least in terms of DNA sequencing, is at the micro level.

Instead of thinking of phenotypes (the bodies which house our genetic codes), focus on genotypes which are incredibly small. So small, in fact, that we cannot see even one complicated strand of DNA with our naked eye.

At the molecular level, deoxyribonucleic acid isn't concerned with our macro issues of whether something is a defined species or not. At these tiny scales, it is merely a question of biochemistry. And since humans and chimpanzees and dolphins and bananas all share the same language code (remember, it comes down to a four letter molecular alphabet), at the microscopic level there isn't a thick brick wall dividing DNA into invariant species categorizations which has a sign to all intruding and stray polynucleotides: *Stay Away*. No, rather it is more akin to alphabet cereal (though this cereal only has the letters C, T, A, and G) or alphabet soup where the letters are free to roam wherever they please within the medium of milk or broth. It isn't a question at this realm of a whether a species can mutate into another, but rather if adenine ("A") can bond with thymine ("T") in a complementary base pairing (it can), or if cytosine ("C") can bond in a similar way with guanine ("G")—it can also. In other words, the macro issue of species never emerges at this quartered off biochemical level. Rather, it is a word used after the fact to describe built-up differences of DNA sequencing. The DNA itself is the same and thus the notion of speciation isn't about C or T or A or G, but rather about how these already given molecular clusters form into larger scaffolding projects. Thus if you accept micro-evolution within a species, you have already de facto accepted evolution itself, since all DNA manipulation (which is how evolutionary change occurs over time in organic beings) is at the micro level. As the Brown University *Course on Evolution* explains it:

For evolutionists the revolution in DNA technology has been a major advance. The reason is that the very nature of DNA allows it to be used as a "document" of evolutionary history: comparisons of the DNA sequences of various genes between different organisms can tell us a lot about the relationships of organisms that cannot be correctly inferred from morphology. One definite problem is that the DNA itself is a scattered and fragmentary "document" of history and we have to beware of the effects of changes in the genome that can bias our picture of organismal evolution.

Two general approaches to molecular evolution are to 1) use DNA to study the evolution of organisms (such as population structure, geographic variation and systematics) and to 2) to use different organisms to study the evolution of DNA. To the hard-core molecular evolutionist of the latter type, organisms are just another source of DNA. Our general goal in all this is to infer process from pattern and this applies to the processes of organismal evolution deduced from patterns of DNA variation, and processes of molecular evolution inferred from the patterns of variation in the DNA itself. An important issue is that there are processes of DNA change within the genome that can alter the picture we infer about both organismal and DNA evolution: the genome is fluid and some of the very processes that make genomes "fluid" are of great interest to evolutionary biologists. Thus molecular evolution might be called the "natural history of DNA.

As for why we don't see as many transitional forms as one might expect, this too is a misleadingly framed question, since it implies that such should be easy to find. Quite the opposite is true. The fact that we have found as many as we have is astounding itself, given that the theory of evolution has only been accepted for less than two centuries. And even while accepted in the scientific community, how many researchers are there worldwide trying to unearth these very rare and precious documents of our ancestral past? My husband, David, who is a fond lover of Coca Cola, makes a fitting analogy here. He remembers back in the late 1950s and 1960s when cans of coke did not have the opening tabs we have today. Rather, one had to use a can opener (usually with one opening larger than the other). When can opening tabs were introduced they were clumsy and slightly dangerous. But Coke can tops have undergone an extensive evolution. As one blogger on the subject explains it:

In the early 1960's the Pittsburgh Brewing Company introduced "Iron City Beer" in 'self-opening cans.' The concept was pretty novel – just pull up on a tab and you had an open can of beer in your hand! No accessories like a 'church key' or bottle opener necessary - imagine that! These early pull tabs were known as "zip tops" and were disposable. But because of the rough edges of the aluminum, the cans often left people with cuts on their fingers, lips and even noses.

By 1965 the design was changed to the ring style, which I'm sure every metal detectorists has seen his or her share of. The ring style was even easier then the zip top; just put your finger into the ring, yank forward and have your beverage with less potential for physical injury - even better!

Needless to say, the swift evolution of the zip top to the ring tab revolutionized canned beverages. By the mid-60's over 75% of all cans produced in the U.S. had a pull-tab opening.

Ten years after the "ring" version of the pull tab was introduced, an answer to this environmental and safety nightmare finally came. The "stay tab" style was introduced in 1975 by the Falls City Brewing Company, and they were here to stay – literally. These ring-style-stay-tabs are what we can see on every can of coke and beer in the grocery store today. Unfortunately, they don't stay quite as well as the designers would have liked. But at least this style doesn't force people to throw the tab aside… they actually have to do a little work to get it off.

However, today there are many students in college who are unaware of the evolution behind opening tabs on coke cans and other soft drinks. Indeed, there haven't been just three stages in this evolution but many small incremental changes, most of which have gone unnoticed. If you look just at a Coke can of the 1950s and a Coke can of today, you might ask where did all the transitional forms go? How easy would it be to find each and every modification over the last fifty or so years?

Unless you are an avid collector it wouldn't be easy at all, since most of the cans have been discarded and thus their respective histories have been smashed or buried. I bring up this analogy because there are millions of such canned fossils waiting to be found but it would take inordinate amounts of time and patience to unearth them, if one hadn't already kept a record of it as the cans were improved over time--and this is about an object for which we have tremendous amounts of information. Imagine how difficult it must be to find transitional forms of our ancestors that lived millions of years ago? So many conditions have to be right for us to be lucky enough to find even one example, much less several.

Kathleen Hunt elaborates on this her website on transitional forms in the fossil record:

The first and most major reason for gaps is "stratigraphic discontinuities", meaning that fossil-bearing strata are not at all continuous. There are often large time breaks from one stratum to the next, and there are even some times for which no fossil strata have been found. For instance, the Aalenian (mid-Jurassic) has shown no known tetrapod fossils anywhere in the world, and other stratigraphic stages in the Carboniferous, Jurassic, and Cretaceous have produced only a few mangled tetrapods. Most other strata have produced at least one fossil from between 50% and 100% of the vertebrate families that we know had already arisen by then (Benton, 1989) – so the vertebrate record at the family level is only about 75% complete, and much less complete at the genus or species level. (One study estimated that we may have fossils from as little as 3% of the species that existed in the Eocene!) This, obviously, is the major reason for a break in a general lineage. To further complicate the picture, certain types of animals tend not to get fossilized – terrestrial animals, small animals, fragile animals, and forest-dwellers are worst. And finally, fossils from very early times just don't survive the passage of eons very well, what with all the folding, crushing, and melting that goes on. Due to these facts of life and death, there will always be some major breaks in the fossil record. Species-to-species transitions are even harder to document. To demonstrate anything about how a species arose, whether it arose gradually or suddenly, you need exceptionally complete strata, with many dead animals buried under constant, rapid sedimentation. This is rare for terrestrial animals. Even the famous Clark's Fork (Wyoming) site, known for its fine Eocene mammal transitions, only has about one fossil per lineage about every 27,000 years. Luckily, this is enough to record most episodes of evolutionary change (provided that they occurred at Clark's Fork Basin and not somewhere else), though it misses the most rapid evolutionary bursts. In general, in order to document transitions between species, you specimens separated by only tens of thousands of years (e.g. every 20,000-80,000 years). If you have only one specimen for hundreds of thousands of years (e.g. every 500,000 years), you can usually determine the order of species, but not the transitions between species. If you have a specimen every million years, you can get the order of genera, but not which species were involved. And so on. These are rough estimates (from Gingerich, 1976, 1980) but should give an idea of the completeness required. Note that fossils separated by more than about a hundred thousand years cannot show anything about how a species arose....

But even with these severe limitations, archaeologists have already unearthed a number of very impressive transitional fossil remains. This is quite remarkable, as we have pointed out, given the inordinate difficulty inherent in trying to discover biological remnants that are still intact.

Here is just a partial list of transitional forms among amphibians as noted on Hunt's site:

Temnospondyls, e.g Pholidogaster (Mississippian, about 330 Ma) -- A group of large labrinthodont amphibians, transitional between the early amphibians (the ichthyostegids, described above) and later amphibians such as rhachitomes and anthracosaurs. Probably also gave rise to modern amphibians (the Lissamphibia) via this chain of six temnospondyl genera , showing progressive modification of the palate, dentition, ear, and pectoral girdle, with steady reduction in body size (Milner, in Benton 1988). Notice, though, that the times are out of order, though they are all from the Pennsylvanian and early Permian. Either some of the "Permian" genera arose earlier, in the Pennsylvanian (quite likely), and/or some of these genera are "cousins", not direct ancestors (also quite likely). Dendrerpeton acadianum (early Penn.) -- 4-toed hand, ribs straight, etc. Archegosaurus decheni (early Permian) -- Intertemporals lost, etc. Eryops megacephalus (late Penn.) -- Occipital condyle splitting in 2, etc. Trematops spp. (late Permian) -- Eardrum like modern amphibians, etc. Amphibamus lyelli (mid-Penn.) -- Double occipital condyles, ribs very small, etc. Doleserpeton annectens or perhaps Schoenfelderpeton (both early Permian) -- First pedicellate teeth! (a classic trait of modern amphibians), etc.

We have a mistaken notion about evolution because we tend to think only at the level of large body types, forgetting that the real changes occur at the biochemical level and even the smallest change there can have a dramatic impact on its eventual housing. While morphological evidences of evolution should by definition be scarce and difficult to precisely piece together (given that ideal conditions must be met on a series of fronts), the most remarkable evidence for evolution is found exactly where it should be uncovered: at the level of DNA.

Sean Carroll has written a popular account of this wonderful breakthrough in evolutionary biology entitled *The Making of the Fittest.* The Howard Hughes Medical Institute provides a nice summary of Carroll's work:

For decades, scientists studying evolution have relied on fossil records and animal morphology to painstakingly piece together the puzzle of how animals evolved. Today, growing numbers of scientists are using DNA evidence collected from modern animals to look back hundreds of millions of years to a time when animals first began to evolve. One of those leading the charge is molecular biologist Sean Carroll.

Carroll's research focuses on the way new animal forms have evolved, and his studies of a wide variety of animal species have dramatically changed the face of evolutionary biology. Using genetics and the tools of molecular biology, he is looking back to the dawn of animal life some 600 to 700 million years ago. It is so long ago that there are virtually no fossils or other physical clues to indicate what Earth's earliest animals were like.

"Evolution encompasses all of biology—it is our big picture," Carroll said. "When I was a student, we had a grand picture of animal evolution from the fossil record, but no knowledge whatsoever of how new animal forms arose. That is the mystery that I want to tackle."

Carroll's studies have uncovered evidence that an ancient common ancestor—a worm-like animal from which most of the world's animals evolved—had a set of "master" genes to grow appendages, such as legs, arms, claws, fins, and antennas. Moreover, Carroll noted, these genes were operational at least 600 million years ago and are similar in all animals, from humans to vertebrates, insects, and fish. What is different, however, is the way these genes are expressed, leading some animals to develop wings, and others to grow claws or feet.

"We found the same mechanism in all the divisions of the animal kingdom," Carroll noted. "The architecture varies tremendously, but the genetic instructions are the same and have been preserved for a very long period of time."

Carroll is also probing the common fruit fly, Drosophila melanogaster, to elucidate how genes control the development and evolution of animal morphology, or form. This innovative approach to studying evolution has led scientists to a more detailed understanding of how animal patterns and diversity evolve.

By analyzing the genetic origin of the decorative spots on a fruit fly wing, Carroll has discovered a molecular mechanism that helps to explain how new patterns emerge. The key appears to lie in specific segments of DNA, rather than genes themselves, that dictate when during development and where on an insect's body proteins are produced to create spots or other patterns.

The same molecular mechanism is likely at work in other animals, including humans, and helps to explain the pattern of stripes on a zebra or the technicolor tail of the peacock. Carroll and his colleagues chose to study the evolution of the wing spot on fruit flies because it is a simple trait with a well-understood evolutionary history. While ancient fruit fly species lack spots, some species have evolved spots under the pressure of sexual selection. The wing spots offer a survival advantage to males, who depend on the decorations to "impress" females to choose them in the mating process.

The discovery is important because it provides critical evidence of the way that animals evolve new features to improve their chances of reproductive success and survival. "We now have convincing proof that evolution occurs when accidental mutations create features such as spots or stripes that impart an advantage for attracting mates, hiding from or confusing predators, or gaining access to food," Carroll explained. "These accidents are then preserved as small changes in the DNA."

At this point in the lecture, most of my students are nodding their head about the logic of evolution, even though they may not agree with all the pointed details.

Evolution by natural selection is, as Daniel Dennett rightly pointed out in his book *Darwin's Dangerous Idea,* based on the notion of methodological naturalism, whereby one attempts to explain all phenomena by its constituent parts. Paul and Patricia Churchland have called this approach intertheoretic reductionism. Take any physical object and you have two fundamental options in trying to explain it. Either it is material or it is not. If the former you try to ground your explanations in physics, chemistry, biology, psychology, and sociology—with an eye and ear to the ground from which these emergent structures arise. If the latter, you are engaged in a metaphysical enterprise, where things are explained not by other material substances but transcendent, even spiritual, realities. Dennett has invoked a nice metaphor to explain these different approaches: science is a crane like approach, and follows an algorithmic (step by step procedure) mindset, even if one is allowed all sorts of wild imaginings provided they are ultimately tested and verified by empirical experiments. Religion, on the other hand, is a sky hook and tends toward non-algorithmic explanations.

This is why evolution is such a powerful idea. It explains so much so simply. Dennett has called it the single greatest idea in the history of human thought, since it serves as the backbone for almost every one of the sciences—from astronomy to neuroscience. As Theodosius Dobzhansky, one of the architects of the neo-synthesis of evolutionary theory in the mid-20th century points out, "Nothing in biology makes sense except in the light of evolution."

It is right at this juncture that I raise a larger philosophical issue in my lecture. If evolution by natural selection (and other selective or eliminative forces) can indeed explain why Shaun looks the way he does, can it also help explain why Shaun thinks the way he does?

Part Two: Explaining Consciousness

In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown on the origin of man and his history.

–Charles Darwin

Why do we think the way we do? Or, more in line with the theme of philosophy, why does the question "why" arise so much in human beings?

There have been, to be sure, many answers to these queries from time immemorial. Countless religions have been created to resolve these perennial questions, each with differing successes. Even science has gotten into the fray with the blossoming of psychology as a distinct discipline in the latter part of the 19th century.

Charles Darwin made a very pregnant prediction near the end of his classic 1859 tome when he opined that evolutionary theory would radically transform other fields of research. He even went so far as to say that "Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and gradation." He could have just as easily substituted Philosophy.

While there have been some remarkable developments in evolutionary psychology, a field previously known more controversially as sociobiology, there hasn't been the same attention given to philosophy. Historically, this may be due to the fact that Herbert Spencer, an early champion of fusing philosophy and evolution and a quite popular advocate of such during his lifetime, became something of anathema during the latter part of the 19th and early 20th century because of some of his more controversial views, particularly Social Darwinism. As the entry on him in *Wikipedia* notes: "Posterity has not been kind to Spencer. Soon after his death his philosophical reputation went into a sharp and irrevocable decline. Half a century after his death his work was dismissed as a 'parody of philosophy' and the historian Richard Hofstadter called him the 'the metaphysician of the homemade intellectual and the prophet of the cracker-barrel agnostic.'"

Combining philosophy with evolution can be fraught with peculiar dangers, not the least of which is a tendency towards what Dennett has called "cheap reductionism," explaining away complex phenomena instead of properly understanding it. Nevertheless, it is even more troublesome to ignore Darwinian evolution because it illuminates so many hitherto intractable problems ranging from epistemology to ethics.

The new field of evolutionary philosophy, unlike its aborted predecessors of the past, is primarily concerned with understanding why Homo sapiens are philosophical in the first place. It is not focused on advocating some specific future reform, but rather in uncovering why humans are predisposed to ask so many questions which, at least at the present stage, cannot be answered. In other words, if evolution is about living long enough to transmit one's genetic code, how does philosophy help in our global struggle for existence?

To answer that question and others branched with it, one has to deal with the most complex physical structure in the universe—the human brain. Because it is from this wonder tissue, what Patricia Churchland has aptly called "three pounds of glorious meat," that all of human thought, including our deep and ponderous musings, is built upon. Take away the human brain and you take away all of philosophy.

Therefore, if we are to understand why philosophy arose in the first place, we have to begin with delving into the mystery on why consciousness itself arose. And to answer that question we first have to come to grips with Darwin's major contribution to evolutionary theory—natural selection. Why would nature select for awareness, especially the kind of self-conscious awareness endemic to human beings, when survival for almost all species is predicated upon unconscious instincts? What kind of advantage does self-reflective consciousness confer that would allow it to emerge and develop over time?

I thought long and hard over this question and for many years I never found a satisfactory response. It was only when I began working as a Research Assistant for Professor V.S. Ramachandran at UCSD, where we focused on visual perception, that I realized that the answer to consciousness was intimately related to Darwinian natural selection. When I started to think in evolutionary terms, it became clearer to me that I had been asking the wrong sorts of questions, especially as I tended to relate my philosophical musings with my religious upbringing.

It may be simply a coincidence but I noticed that after I had met with Francis Crick at a dinner party hosted by Ramachandran in his La Jolla home my questions became more focused and thus I proceeded upon a more fruitful line of inquiry. Ironically, I didn't know that the person I was introduced to at the party was a world famous scientist who along with James Watson had discovered the double-helix structure of DNA. Ramachandran simply introduced the Nobel laureate as Francis. Since we were the first guests at the party we ended up chatting on the nearby couch. However, we both became so absorbed in our conversation that we ended up talking for nearly two straight hours. At the time I thought Francis was a second-fiddle to his artist wife, since he never gave any indication of his remarkable credentials. For all I knew he was either retired or out of a job. When I asked Crick what he did for a living he smirked and said, "Ah, I dabble in a little bit of this and a little bit of that," never once revealing his vast background in molecular biology.

Francis learned of my interest in Eastern Philosophy, Gnosticism, and my advocacy of vegetarianism. He tried to provoke me a bit, but because I didn't think he was all that knowledgeable in these areas I passionately, but hopefully reasonably, gave him my counter-arguments. Crick seemed slightly bemused by my candor and complete lack of awe in his presence. I even had the audacity of suggesting that he could help me out in the lab at UCSD with the experiments we were doing. It was only later to my and everyone else's chagrin when I realized (and to my horror) that I was debating with such an eminent mind. Thankfully, and to his great credit, Francis Crick never let on during the entire conversation who he was.

What stood out to me both during and after our conversation was Crick's insistence that I should focus my graduate studies on neuroscience, since he argued that the brain was the key to unraveling many of life's greatest mysteries. Although I didn't at the time take Francis' advice, his suggestion stayed with me over the years and has clearly influenced my thinking on how to approach the study of consciousness.

My husband (who did his Ph.D. at UCSD) was also interested in why consciousness evolved and had since 1991 embarked on an intensive study of physics and neuroscience to better resolve the issue.

I still remember the day he came home from his teaching duties at CSULB and exclaimed that the answer to the riddle of consciousness was remarkably simple and obvious. So obvious, in fact, that he wondered why he hadn't dawned on him much earlier. In his typically Socratic way, he peppered me with a series of loaded questions designed to make clearer his epiphany. Watching our son growing up, said my husband, was the triggering event. As my husband recounted in his diary of that day,

I am learning more about the human brain and philosophy from Shaun than I ever did from books. It is now very obvious and clear to me that whatever questions we ask of the universe arise because of the architecture of our brain. More precisely, philosophy is the result of differing brain states and upon that contingent scaffolding we come up with varying questions to ask of the world and its participants, though we never seem to realize that such questioning has less to do with reality per se and more to do with our own evolutionary needs. Ah, I can put it better yet: philosophy is like heartburn. It is the natural result of something that didn't digest well. I will call it brain burn.

What does such a neologism mean? Every deep question we have, every deep thought we ponder, is the result of the confusion of a neural system when confronted with its own dissociation. Consciousness is dissociation. And therein lays its Darwinian advantage, since most of our awareness is in our head it doesn't have to face the very real and empirical and deathly consequences of being without. Being within survives. Being without tends to end up dead. So consciousness arises as dissociation so it can play out (via its internal machinations. . . what we call imagination/daydreaming) without physical harm alternative scenarios to secure its Four F'S: *F..k, Food, Flee, Fight.* Consciousness is literally a virtual simulator and that is why it has been so helpful in allowing humans to survive globally, even when our bodies were not adapted to certain environmental niches.

If you can imagine without real consequence, then you have a better chance of living if you have already played out (internally, but not externally) competing strategies. Those without consciousness don't have this liberty and thus when they do play out a choice, they so in a real world. And in such a real world, if it doesn't work you are eaten. In imagination, in consciousness, you can play as if it is real and project all sorts of end game earnings to see which one would be to your advantage. Consciousness is the brain's way of making chance/chaos (read nature) more plastic, more pliable, more beneficial to the host organism.

What is the best way to survive chance contingencies? By developing a statistically deep understanding of what varying options portend. Consciousness is a way around pure chance by developing an internalized map of probabilities which can be visualized internally without having to be outsourced prematurely. Being in your head is another way of avoiding being stuck in only a one way avenue of recourse. Any reproducing DNA that can develop a virtual simulator within itself has a huge advantage over a genetic strand that cannot.

The gurus and mystics have it completely wrong. The world isn't an illusion; consciousness is. But even if we say consciousness is an illusion--which it is (in the sense that its stuff is literally composed of dreams and other sorts puffery)--that doesn't mean it isn't helpful to our survival. It is. Consciousness is a body's way of giving itself a better chance when confronted with the reality of Chance itself. Consciousness is probability functions envisioned.

Ah, but we humans are so naive. We were so mesmerized by the theatre of consciousness that we forgot that it was the body that was real, not its projected sideshow. So I won't be misunderstood. What I am saying is the direct opposite of religion, of mysticism, of guruism. Consciousness isn't the strongest part of a human being. It is not going to survive. There is no soul. Nietzsche was right. Consciousness is the weakest element of a human being, though we believe otherwise. Film is fragile, so is our awareness. Nobody believes that a reel of film is going to reincarnate or survive in the afterlife. Awareness is Poker Self-Reflective. Chance giving itself better odds.

My husband had been reading various articles by Ramachandran and a number of books by the Nobel laureate in medicine, Gerald Edelman (most popularly known for his introduction of Neural Darwinism) where they had implied that consciousness was more or less a virtual simulator. "That's it," Dave echoed.

"Think about what consciousness does most of the time. It simulates its environment in order to make the best probable guesses about how to respond to it. But in order for such simulations to be wide-ranging, there has to be an allowance for lots of projections or end game results which are purely fantastical and have no concordance with empirical reality. Otherwise, the very basis of imagination would be too stilted and wouldn't be amenable to new situations, new environments, and new problems."

At this point I chimed in with Stephen Jay Gould's notion of spandrels, the unintended consequences or secondary effects of a more primary adaptation. If consciousness is an evolutionary adaptation which allows for any sophisticated strand of DNA to develop a virtual navigating device within itself, thereby increasing its odds by allowing for a prior contemplation of varying strategies before making a decisive and decidedly empirical decision, then it is quite reasonable to expect that there should be much in a virtual simulator which is merely imaginary and has no real world correlate. This would easily explain why many of our projections are delusional. If consciousness is a probability adjustor (played out in our minds replete with an emotional feedback loop), then sometimes we will opt for strategies that are indeed wrong, misguided, and illusionary. They are just part of the odds. If this is true, then we should expect certain mental states which would deviate from the mean. Is this the basis for all mental diseases?

But as I was partnering these ideas with my husband, I realized that even calling something a mental disease implied an already fixed understanding of what constituted normal awareness. If consciousness is simulating its environment so as to better its odds when it does indeed make a real life choice, then much of its success is due to how well it actually matches up with and predicts the incoming stimuli. Consciousness could never have survived the brutal machinations of natural selection unless it was somewhat accurate in how it modeled its exterior environment. If it came up with simulations that were continually mistaken, it would have been eaten up by a predator long ago. No, consciousness must be on whole a fairly accurate modeler of the outside world in order to confer the benefit necessary to evolve as a significant adaptation. That there will be glitches and mistakes and illusory detours is to be expected, but overall those have to be kept at a minimum since otherwise the very advantage that consciousness confers as a virtual simulator would be automatically lost. If consciousness was merely projections of our temporal lobes, it wouldn't have any real world benefit, but would act as a punishing (and ultimately eliminating) detriment.

As we discussed this theory of consciousness further, we started to see the powerful utility of Gerald Edelman's binary idea of *Second Nature.* Edelman makes a distinction between first order and second order consciousness, or what he calls first nature and second nature levels of awareness. As the *Wilson Quarterly* review of his book, *Second Nature*, explains:

In *Second Nature*, Nobel Prize winning neuroscientist Gerald Edelman proposes what he calls "brain-based epistemology," which aims at solving the mystery of how we acquire knowledge by grounding it in an understanding of how the brain works.

Edelman's title is, in part, meant "to call attention to the fact that our thoughts often float free of our realistic descriptions of nature," even as he sets out to explore how the mind and the body interact.

Edelman suggests that thanks to the recent development of instruments capable of measuring brain structure within millimeters and brain activity within milliseconds, perceptions, thoughts, memories, willed acts, and other mind matters traditionally considered private and impenetrable to scientific scrutiny now can be correlated with brain activity. Our consciousness (a "first person affair" displaying intentionality, reflecting beliefs and desires, etc.), our creativity, even our value systems, have a basis in brain function.

The author describes three unifying insights that correlate mind matters with brain activity. First, even distant neurons will establish meaningful connections (circuits) if their firing patterns are synchronized: "Neurons that fire together wire together." Second, experience can either strengthen or weaken synapses (neuronal connections). Edelman uses the analogy of a police officer stationed at a synapse who either facilitates or reduces the traffic from one neuron to another. The result of these first two phenomena is that some neural circuits end up being favored over others.

Finally, there is reentry, the continued signaling from one brain region to another and back again along massively parallel nerve fibers. Since reentry isn't an easy concept to grasp, Edelman again resorts to analogy, with particular adeptness: "Consider a hypothetical string quartet made up of willful musicians. Each plays his or her own tune with different rhythm. Now connect the bodies of all the players with very fine threads (many of them to all body parts). As each player moves, he or she will unconsciously send waves of movement to the others. In a short time, the rhythm and to some extent the melodies will become more coherent. The dynamics will continue, leading to new coherent output. Something like this also occurs in jazz improvisation, of course without the threads!" Reentry allows for distant nerve cells to influence one another: "Memory, imaging, and thought itself all depend on the brain 'speaking to itself.'"

In Edelman's view sentient creatures have (to greater or lesser degrees) first order awareness or consciousness, including human beings. But such awareness is merely rudimentary and is not yet self reflective; it is more akin to being aware of something exterior to one's self, but not yet being able to reflect upon what that means. It is like looking at a mirror but without any comprehension of what that reflection is or means. Second nature, or second order awareness, is when we look at a mirror and develop a feedback loop and have the ability to ponder over what it means. If first nature is a way for our senses to reach out to the world and receive stimuli and have our instincts respond accordingly, second nature is our ability to absorb such information and have the wherewithal to reconstruct models of varying probabilities about what this information means. Second nature allows us to simulate our environment in ways not possible with first order awareness. In this sense, it confers a dramatic Darwinian advantage because simulations allow for better odds in our ultimate reactions to whatever stimuli or information we encounter.

As the Edelman entry on *Answers.com* explains further:

Edelman was struck by a number of similarities between the immune system and the nervous system. Just as a lymphocyte can recognize and respond to a new antigen, the nervous system can respond similarly to novel stimuli. Neural mechanisms are selected, he argued, in the same manner as antibodies. Although the 109 cells of the nervous system do not replicate, there is considerable scope for development and variation in the connections that form between the cells. Frequently used connections will be selected, others will decay or be diverted to other uses. There are two kinds of selection: developmental, which takes place before birth, and experiential. There are also innate 'values' – built in preferences for such features as light and warmth over the dark and the cold.

In Edelman's model, higher consciousness, including self-awareness and the ability to create scenes in the mind, have required the emergence during evolution of a new neuronal circuit. To remember a chair or one's grandmother is not to recall a bit of coded data from a specific location; it is rather to create a unity out of scattered mappings, a process called by Edelman a 'reentry'. Edelman's views have been dismissed by many as obscure; some neurologists, however, consider Edelman to have begun what will eventually turn out to be a major revolution in the neurosciences.

As the Guardian newspaper elaborates:

The degree to which an organism is conscious is therefore dependent on the complexity of its brain. Large-brained mammals such as dogs have a core self-consciousness. Humans, perhaps uniquely, have a reflexive and recursive consciousness - we are conscious of being conscious.

Human consciousness is thus an evolved property, the inevitable consequence of having brains of a particular complexity.

What David and I found most intriguing in Edelman's theory was his fundamental understanding what of consciousness does. As Steven Rose summarizes Edelman's definition, "What consciousness does, he says, is to "inform us of our brain states and is thus central to our understanding."

Awareness, therefore, is indeed a theatre for the mind in which varying trajectories are given stage time to play out their respective hunches. But because this is a theatre and not the outside world as such, many things are acted out as if they were indeed real. And herein lays the ultimate danger of such an awareness. One can too easily conflate one's neural state for the real state of the world at large. Freud, whom Edelman both praises and criticizes, often remarked that one of his greatest discoveries was psychic transference. As Alun Jones explains:

Freud described transference as "new editions and facsimiles of impulses and phantasies" (1923/1953, p. 82) originating in the past. Instead of remembering, the person transfer attitudes and conflicts are enacted in current relationships, sometimes with unfortunate results. Manifestations are likely to occur in all human encounters; feelings toward the significant other often begin to emerge early on in relationships.

Freud's notion of transference is what consciousness was evolved to do. For instance, in our early childhood our awareness developed several models about what was happening, especially in a situational crisis. If that model was believed and sustained to a given extent, then it is quite likely to be invoked again if a similar occasion arose. The problem, of course, is that the new dilemma may have little resemblance to the prior one and thus our projected transference may be of little help. But even here the transference is of use psychologically if we can see it for it was and is: "information about our brain state and its attendant emotions."

While Edelman rightly discounts Freud's psychoanalytic technique, he does nevertheless appreciate Freud's rich and nuanced understanding of how consciousness may operate. Freud may have been technically incorrect in his analysis of why such mental problems arise and how to resolve them, but he was an insightful cartographer of psychic ailments.

The problem of consciousness is, as Freud rightly suspected, revealed by dreaming, since it gives us a clue about how consciousness must have first emerged. As we all know there are several stages of awareness in our dreams—ranging from the hallucinatory and intangible impressions one might get from a severe lack of rest to the elevated heights of lucidity when one experiences an acute sense of clarity and self luminosity. Our waking state awareness is built upon the feeling of certainty, and to the degree that we can believe what our mind projects the more likely we are to act upon it, rightly or wrongly. Thus the hallmark of a heightened sense of awareness is how certain and definite it feels. This is an important feature to differentiate since if we lacked this clarity we would be less willing to act and to make choices. And if we hesitate in face of a real danger (a lion, a tiger, a bear, oh my!), then we run the very real risk of being eaten. An awareness that couldn't make such fine tuned adjustments would have been eliminated long ago in our ancestral past.

But herein lies the problem. To the degree that consciousness "works" because it conflates our brain state with the current "real" state of the world around us, it runs the risk of not being pliable enough to adapt to a new set of circumstances. In other words, consciousness must have enough "plasticity" to make judgments that turn out to be wrong, provided those mistaken assumptions error on the side of being too conservative or too safe.

A classic example of this, albeit wildly over stated here for our purposes, is the hypothetical case of an animator versus a non-animator. Imagine for argument's sake that hundreds of thousands of years ago there existed two kinds of human beings. One who tended to believe in animism, whereby ordinary objects possessed an "animated" or "vital" or "soul" force replete with the same kind of intentionality, though perhaps more mysterious, than we have. The other human being lacked such animating tendencies and thus had a more limited way of deciphering the motivations or intentions of other objects. Now, let's further imagine that both of these individuals were brothers sitting around a camp fire and there was the sound of a rustling bush. The animator, given his predisposition to project (Freud's transference writ early?), imagines all sorts of possibilities and because of the emotions he attaches to each (and keeping in mind the conservative nature of how such a state of awareness must have in order to survive) will on average try to protect himself and thus run and hide or protect himself under the worst case scenario. The non-animator, however, will do no such thing and in his "realist" approach most likely stay put and not animate anything whatsoever about the rustling bushes.

Now it may well be that the non-animator is correct much more often than the animator (most of the time it is just the wind against the leaves), but if the animator is right just 1/10 of the time his conservative, though animistic, approach has saved his life and thereby allowed him to live another day in order to pass on his genetic code. The non-animator, even if he was correct more often than his counterpart, ends up eaten and dead, and thus reducing his chances to pass on his DNA.

While this example is hyperbolic to the extreme, it does underline something about animism and about why such an innate tendency may have evolved in human beings. Projections are future oriented and any awareness that can better predict the future will be of some survival benefit. But the future is unknown, and therefore making predictions about it is inherently a probabilistic venture. Therefore if consciousness arose at least to some small measure as a predictor of how to react to future but unknown events, then it must error on the side of caution. Otherwise, if awareness was too adventurous whatever advantages it gained would be prematurely lost with one bad outcome.

But this conservative approach of awareness would most likely only be necessary when an individual confronted what he or she perceived to be a "real" or "certain" crisis. In other words, a virtual simulator would only be cautious if it acted upon that simulation as if it related to a real event. If, however, the virtual simulator knew or believed beforehand that the simulation wasn't going to be invoked immediately and thus could be contemplated upon without any empirical test, then it could allow itself the freedom of a wide arrange of imaginings. It could, to invoke a cliché, "day dream." It could fantasize. It could conjure up all sorts of nonsense, provided that it wasn't forced into an early test case.

Here we are starting to see what dreaming portended for waking state awareness. Dreams, by definition, are subjective conjurings that arise when we are asleep. This is another way of saying that when consciousness doesn't have to "work" or be called into the line of fire, it has the freedom to mix and match all sorts of images and sounds and feelings into a Picasso like universe.

This would be the precursor of a consciousness which had to act upon one of its modeling simulations. Dream first, act later. And this is apparently what consciousness has evolved to do and why it has been of such a huge advantage to Homo sapiens. Unlike other animals, which apparently do not possess Edleman's second nature, human beings can play out innumerable scenarios in the privacy and safety of their own head until such time that they can draw upon this rich rolodex of imagined trajectories and select what he or she believes is the best approach or model to apply to the present circumstance or problem.

To appreciate how effective and powerful this tool can be for any competitive organism, just ask yourself this question: Who would your rather have fly your airplane: a pilot who never underwent any flight simulations or one who underwent hundreds of hours in a flight simulator? The answer is obvious. Indeed, one can draw from many other professions to see the inherent advantages to virtual modeling or simulation. Most of the top athletes in the world today—from Tiger Woods to Kelly Slater to Michael Jordan—have repeatedly emphasized the importance of visualizing their performance before it happens. Whether it is going over and over in your head how to shoot a basketball in a hoop, or how to stand up quickly to ride a wave at Pipeline, or how to line up a long putt, the more time that is spent simulating the event the better off one feels when actually confronting the real occasion.

So if consciousness did indeed evolve over long epochs of time, we should expect to see varying gradations of awareness depending more or less on the complexity of the neuronal architecture that gives rise to it. Human awareness, though appearing unique and distinct, represents one end of the spectrum of consciousness. If awareness, as Crick and others points out, is intimately connected how our brain functions, then we should expect to see forms of higher awareness or even cognitive function in mammals closely aligned with us from our evolutionary past. And as recent studies in animal behavior have shown, this is precisely what researchers have found. As Donald R. Griffin points out in Animal Minds:

Must we reject, or repress, any suggestion that the chimpanzees or the herons think consciously about the tasty food they manage to obtain by these coordinated actions? Many animals adapt their behavior to the challenges they face either under natural conditions or in laboratory experiments. This has persuaded many scientists that some sort of cognition must be required to orchestrate such versatile behavior. For example, in other parts of Africa chimpanzees select suitable branches from which they break off twigs to produce a slender probe, which they carry some distance to poke it into a termite nest and eat the termites clinging to it as it is withdrawn. Apes have also learned to use artificial communication systems to ask for objects and activities they want and to answer simple questions about pictures of familiar things. Vervet monkeys employ different alarm calls to inform their companions about particular types of predator.

Such ingenuity is not limited to primates. Lionesses sometimes cooperate in surrounding prey or drive prey toward a companion waiting in a concealed position. Captive beaver have modified their customary patterns of lodge- and dam-building behavior by piling material around a vertical pole at the top of which was located food that they could not otherwise reach. They are also very ingenious at plugging water leaks, sometimes cutting pieces of wood to fit a particular hole through which water is escaping. Under natural conditions, in late winter some beaver cut holes in the dams they have previously constructed, causing the water level to drop, which allows them to swim about under the ice without holding their breath.

Nor is appropriate adaptation of complex behavior to changing circumstances a mammalian monopoly. Bowerbirds construct and decorate bowers that help them attract females for mating. Plovers carry out injury-simulating distraction displays that lead predators away from their eggs or young, and they adjust these displays according to the intruder's behavior. A parrot uses imitations of spoken English words to ask for things he wants to play with and to answer simple questions such as whether two objects are the same or different, or whether they differ in shape or color. Even certain insects, specifically the honeybees, employ symbolic gestures to communicate the direction and distance their sisters must fly to reach food or other things that are important to the colony.

Although these are not routine everyday occurrences, the fact that animals are capable of such versatility has led to a subtle shift on the part of some scientists concerned with animal behavior. Rather than insisting that animals do not think at all, many scientists now believe that they sometimes experience at least simple thoughts, although these thoughts are probably different from any of ours. For example, Terrace (1987, 135) closed a discussion of "thoughts without words" as follows: "Now that there are strong grounds to dispute Descartes' contention that animals lack the ability to think, we have to ask just how animals do think." Because so many cognitive processes are now believed to occur in animal brains, it is more and more difficult to cling to the conviction that this cognition is never accompanied by conscious thoughts.

Conscious thinking may well be a core function of central nervous systems. For conscious animals enjoy the advantage of being able to think about alternative actions and select behavior they believe will get them what they want or help them avoid what they dislike or fear. Of course, human consciousness is astronomically more complex and versatile than any conceivable animal thinking, but the basic question addressed in this book is whether the difference is qualitative and absolute or whether animals are conscious even though the content of their consciousness is undoubtedly limited and very likely quite different from ours. There is of course no reason to suppose that any animal is always conscious of everything it is doing, for we are entirely unaware of many complex activities of our bodies. Consciousness may occur only rarely in some species and not at all in others, and even animals that are sometimes aware of events that are important in their lives may be incapable of understanding many other facts and relationships. But the capability of conscious awareness under some conditions may well be so essential that it is the sine qua non of animal life, even for the smallest and simplest animals that have any central nervous system at all. When the whole system is small, this core function may therefore be a larger fraction of the whole.

Now turning our attention directly to philosophy we are in a better position to understand why the question "why" arises so often in human beings. In light of consciousness as a virtual simulator, any organism that can develop a mental "pivot" tool will have a tremendous advantage in thinking of new and unexpected strategies.

A curious, but hopefully, useful analogy can be derived here from a well known sport. In basketball, for instance, a seasoned player knows well how to use his or her pivot "foot." Once one has finished dribbling the ball, he or she must keep one foot firmly set on the ground. The other foot, however, is free to "pivot" or "revolve" or "turn" giving one options that the other foot doesn't.

Asking "why" is consciousness' pivot foot. It allows for a virtual simulator to turn and think of varying options and what they portend. It allows the mind to revolve and go into different directions. As F. Scott Fitzgerald essayed in his book, *The Crack-Up*: "The test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function." Why is the mind's way of allowing a multiplicity of ideas to compete and hopefully function better because of it.

"Why" is similar to an all-purpose function key on your laptop computer which opens up programs that are otherwise hidden from display. But though asking why can be quite helpful in very specific situations (why does it rain in the winter and not the summer, for example?), it can also serve as unnecessary nuisance if its protestations cannot be adequately met. Perhaps this can help us better understand the wide gulf between religion and science. We have already admitted that for a virtual simulator to be highly effective it must be able to conjure up all sorts of imagined nonsense, provided it doesn't have to always act upon such in a real life situation. Science, though clearly built upon wild speculations and imaginings, is differentiated from religion because it measures its successes by actually "testing" its varying models with each other and placing them in real life contexts to determine which one holds up best under rigorous conditions. Science, in other words, attempts to falsify what consciousness conjures up so as to see which model best explains reality. And in so doing, it allows for a cataloging of both its successes and failures. In this way, science can indeed progress because it has a built-in tendency to eliminate less successful theoretic conjectures. Religion, on the other hand, tends to accept certain simulations above all others without resorting to any empirical verification and habitually substantiates such imaginary permutations as being beyond physical testing. In this way the virtual simulation protects its integrity and truth value by pointing to a transcendent arbiter and thereby foregoing any real world competition lest it be eliminated by such testing. Is it merely coincidence that there are tens of thousands of religions in the world each claiming exclusive truths, but nothing comparable in the world of science. There isn't a Japanese physics or a Tibetan physics or an American physics. There is just physics. What country you come from is secondary. Gravity is universal and doesn't have different acolytes claiming different revelations in different tongues. But which geographical region you come from in religion isn't secondary, but primary, since as every geographer knows the gods change when you go to different landscapes.

Virtual simulation can also be instrumental in helping us better understand why beliefs systems can be so powerful, even when such ideologies can be regarded as wrongheaded or backward. Any meaning system, provided it allows one enough purpose and drive to live another day, is better than none at all. As the script from the movie, Truth Lies, explains it:

Our brains didn't evolve to understand the universe but to literally "eat" it (as in survive the local ecosystem niche long enough to transmit one's genetic code). Thus, we have invariably conflated our appetite with truth. We don't know the truth; we simply know what it takes for us to live skillfully enough so that we don't get eaten too young. And if we live long enough, the redundancies (or spandrels or secondary effects) of our enlarged cerebral cortex allows us the freedom to ponder imponderables and impute upon those mysteries all sorts of silly nonsense with the added caveat that such idiocy will last provided it floats our boat to live another day. Let me rephrase that: nonsense evolved as an adaptive function of an enlarged brain because believing nonsense makes MORE sense (in terms of replicating strategies) than coming to grips with the random chaos from which the universe apparently arises. Tom Blake might put it this way, "nature is without sentiment, but those who FEEL sentiments have a better chance of surviving this horror show than those who do not." Why? Because any meaning is better than no meaning even if the universe ultimately is devoid of purpose. As Voltaire would say in my twisted way of paraphrasing him, "Man would have to invent God even if such a being didn't exist." We cannot live without purpose, even if that purpose is an adaptive fiction evolved over eons of time designed to blind those with such sentiments from the truth that nature has no such sentiment. Ah, too much truth and you cannot move. Too much reality and you become autistic. Which is another way of saying that Jack Nicholson was right all along: we cannot handle the truth. But the truth surely has a good way of handing us. It lies to us in order for us to live an extra day. Think about it. The truth is that truth lies

The idea that our brains could literally deceive us is now well established in neuroscience. Indeed, the brain's capacity for filling in objects that are not present is a vitally important component of how we navigate in our day to day world. As the abstract to "Perceptual filling-in from the edge of the blind spot" on Science Direct explains:

Looking at the world with one eye, we do not notice a scotoma in the receptor-free area of the visual field where the optic nerve leaves the eye. Rather we perceive the brightness, color, and texture of the adjacent area as if they were actually there. The mechanisms underlying this kind of perceptual filling-in remain controversial. To better understand these processes, we determined the minimum region around the blind spot that needs to be stimulated for filling-in by carefully mapping the blind spot and presenting individually fitted stimulus frames of different width around it. Uniform filling-in was observed with frame widths as narrow as 0.05° visual angle for color and 0.2° for texture. Filling-in was incomplete, when the frame was no longer contiguous with the blind spot border due to an eye movement. These results are consistent with the idea that perceptual filling-in of the blind spot depends on local processes generated at the physiological edge of the cortical representation.

The brain is forced to makes these "lying" choices to us as part of its mapping expertise. We are not seeing or hearing or smelling or feeling or touching the world "as it is," but rather as our brains "simulate" it for our evolutionary survival.

In this way philosophy is a multi-faceted procedure to encourage more simulations versus less. When Socrates axiomatically stated that an unexamined life wasn't worth living, he was arguing that we should bring to light more information about why and how we make the decisions we do. In his own inimitable way, Socrates was provoking the virtual simulator which is consciousness to start using its pivot foot (the "Why?") with more dexterity.

Evolutionary philosophy is in many ways similar to the Churchlands' concept of eliminative materialism. As the Neural Surfer website elaborates:

When we scientifically advanced in astronomy, medicine, and physics we replaced the old and outdated concepts of our mythic past with new and more accurate terminology which reflected our new found understanding of our body and the universe at large.

Thus, instead of talking about THOR, the Thunder God, we talked instead about electrical-magnetic currents. Thus, instead of talking about SPIRITS, as the causes of diseases, we talked about bacteria and viruses. Thus, instead of talking about tiny ghosts circulating throughout our anatomies pulling this or that muscle, we talked about a central nervous system.

In sum, we "eliminated" the gods or spirits in favor of more precise and accurate physiological explanations. Hence, the term: "eliminative materialism."

As a materialistic explanation evolves over time, it will either eliminate or reduce hitherto inexplicable phenomena down from the celestial region to the empirical arena. And in so doing, help us to better understand why certain events transpire in our body, in our mind, in our society, and in our world.

Eliminative materialism is reason writ large.

The glitch, though, is that we have allowed eliminative materialism to change our thinking about almost everything EXCEPT ourselves.

When it comes to understanding our own motivations, we have (as the Churchlands' point out) resorted more or less to "Folk Psychology," utilizing terms such as "desire", "motivation", "love", "anger", and "free will", to describe what we believe is happening within our own beings.

The problem with that is such terminology arises NOT from a robust neuroscientific understanding of our anatomies but rather arises from a centuries old MYTHIC/RELIGIOUS comprehension of our very consciousness.

And that's the rub.

Where we have moved away from such religious goo speak in the fields of physics, astronomy, chemistry, and biology, in talking about ourselves we are still stuck in pre-rational modes of discourse. Where astronomy reflects the LATEST theories of the universe, where medicine reflects the LATEST theories of diseases, in talking about ourselves we tend to reflect ANCIENT theories of human psychology.

We resist knowing ourselves as MERELY this body, this brain, this material.

As Patricia so astutely put it, "We don't want to be just three glorious pounds of meat."

Well, according to eliminative materialism, that is PRECISELY what "we" are.

And in order to get a better understanding of human consciousness, neurophilosophy argues that we focus our attention on developing a more comprehensive analysis of the brain and how it "creates" self-reflective awareness.

In so doing, we can then come up with a more neurally accurate way of describing what is going on within our own psyches (pun intended). Thus, instead of using the term "soul" we might instead use phase-specific words to describe the current state of awareness which are more neurologically correlated.

We have already done this slightly when it comes to headaches. Due to our increased attention to various pains and to the various drugs that are effective in treating them, we have become MORE aware of how to differentiate and thereby treat varying types of head pain. From Excedrin (very good for migraines because of the caffeine and aspirin combination) to Advil (very good for body and tooth aches).

Hence, the neurophilosophical way to understand one's "soul" is to ground such ideas in the neural complex.

What may transpire, as Francis Crick suggests in his aptly titled book *The Astonishing Hypothesis*, is that the soul will disappear.

Why?

Because there really is NO soul.

We are rather a bundle of neurons and nerve endings tied to together in a huge neural complex that gives rises to consciousness.

There is nothing META (beyond) physical about us.

We ARE physical.

And that very insight will lead to a reinterpretation of who we are and why we are and how we are.'

If consciousness does indeed serve as a virtual simulator with an amplified probability feedback loop, then it should come as no surprise that one of the more promising theories arising from neuroscience concerning how the brain works is based upon Bayesian probability theory.

From the New Scientist:

Neuroscientist Karl Friston and his colleagues have proposed a mathematical law that some are claiming is the nearest thing yet to a grand unified theory of the brain. From this single law, Friston's group claims to be able to explain almost everything about our grey matter.

Friston's ideas build on an existing theory known as the "Bayesian brain", which conceptualises the brain as a probability machine that constantly makes predictions about the world and then updates them based on what it senses.

The idea was born in 1983, when Geoffrey Hinton of the University of Toronto in Canada and Terry Sejnowski, then at Johns Hopkins University in Baltimore, Maryland, suggested that the brain could be seen as a machine that makes decisions based on the uncertainties of the outside world. In the 1990s, other researchers proposed that the brain represents knowledge of the world in terms of probabilities. Instead of estimating the distance to an object as a number, for instance, the brain would treat it as a range of possible values, some more likely than others.

A crucial element of the approach is that the probabilities are based on experience, but they change when relevant new information, such as visual information about the object's location, becomes available. "The brain is an inferential agent, optimising its models of what's going on at this moment and in the future," says Friston. In other words, the brain runs on Bayesian probability. Named after the 18th-century mathematician Thomas Bayes, this is a systematic way of calculating how the likelihood of an event changes as new information comes to light

Over the past decade, neuroscientists have found that real brains seem to work in this way. In perception and learning experiments, for example, people tend to make estimates - of the location or speed of a moving object, say - in a way that fits with Bayesian probability theory. There's also evidence that the brain makes internal predictions and updates them in a Bayesian manner. When you listen to someone talking, for example, your brain isn't simply receiving information, it also predicts what it expects to hear and constantly revises its predictions based on what information comes next. These predictions strongly influence what you actually hear, allowing you, for instance, to make sense of distorted or partially obscured speech.

In fact, making predictions and re-evaluating them seems to be a universal feature of the brain. At all times your brain is weighing its inputs and comparing them with internal predictions in order to make sense of the world. "It's a general computational principle that can explain how the brain handles problems ranging from low-level perception to high-level cognition," says Alex Pouget, a computational neuroscientist at the University of Rochester in New York (Trends in *Neurosciences*, vol 27, p 712).

Friston developed the free-energy principle to explain perception, but he now thinks it can be generalised to other kinds of brain processes as well. He claims that everything the brain does is designed to minimise free energy or prediction error (*Synthese*, vol 159, p 417). "In short, everything that can change in the brain will change to suppress prediction errors, from the firing of neurons to the wiring between them, and from the movements of our eyes to the choices we make in daily life," he says.

Applying Friston's grand unified theory of the brain to consciousness, it can be argued that while minimizing prediction errors is elemental and particularly relevant for any modeling system working in the real world of life and death, the most marked feature of second order awareness is its dissociation from such real world onslaughts. The fact that our awareness can be freed from the present struggle for existence is perhaps why it is so useful in orienting us to future occasions. To make a crude analogy here, a drowning man doesn't have enough "free" time or energy to do philosophy. His first nature instincts must take over and his reptilian brain survival tools must kick into high gear. However, if the drowning man is saved and is allowed enough leisure time to reflect (another word for simulate) upon what happened to him, he may be able to play out an array of options for escaping just such a dilemma the next time it might happen to him. But this presupposes a surplus of both physical and mental energy which is not already obliged or preoccupied with any over-arching present conundrums.

In light of this necessity for leisure, it can be argued that philosophy can only be practiced in earnest when there is enough free time and energy. A pilot who is flying under enemy fire doesn't have the option to go and ruminate in his mock-up flight simulator. Likewise, philosophy can only arise in a sustained fashion in a culture which has ample time on its hand.

Going back to our basketball analogy, the center can't use his or her pivot foot if he or she is too closely guarded. The same may also be true to some extent with the mental use of our pivotal "why." If conditions are too severe, we won't have the freedom to turn our thinking around or rotate our concepts in new directions. If time is of the essence, philosophy is not. Indeed, one can even propose a syllogism on the basis of this questionable claim. If you are doing philosophy for any measurable period of time, it can be taken as conclusive proof that you have too much of it. This, of course, is not to disparage philosophical inquiry but only to underline how an evolutionary approach to the subject uncovers the basis for why such an endeavor would emerge in the first place and why it can only be practiced under certain optimal conditions.

Part Three: **Recommended Readings**

Ten Annotated Books on Evolution Theory

Darwin's Dangerous Idea: Evolution and the Meanings of Life *by Daniel Dennett*

Daniel Dennett breaks his book up into three sections: the first deals with exactly what Darwin's dangerous idea is; the second section more or less examines the biology of evolution; and third part looks at how Darwinian evolution has transformed our understanding of who and what we are.

Section One:

What is Darwin's dangerous idea? Darwin's idea is the single best idea anyone has ever had, argues Dennett. It is also the most dangerous one. What he means by this is that it burns, like a "Universal Acid," through any misconceptions we have about nature. Special Creation is burned away; the Cosmic Pyramid of God, Mind, Design Order, etc. is annihilated; Plato's essentialism is destroyed; Locke's primacy of Mind is no more. Darwin single handedly demystified the world with his reductionism and usurped all of our traditional understandings in one swoop. He replaced a "skyhook" designer with an algorithmic "crane." And, yes, without a designer, Dennett quipped, there can still be design via this algorithmic process in nature and the statistical probability of design arising after billions of years of hit and miss tries. This is where intelligent design theorists get it wrong: there can be design without a designer. Moreover, this is where "greedy reductionists," who altogether dismiss design apparent all around us, also get it wrong.

Science offers us a totally new perspective of the world and who and what we are, and, hence, science and philosophy forever are intertwined. As with the Copernican Revolution where the shot was heard around the world, Darwin's dangerous idea is still making its way around the world. It took centuries before everyone accepted Copernicus' heliocentric model and it may take the same time or more for the Darwinian Revolution to dominate.

Should we fear this dangerous idea in anyway, asks Dennett? Absolutely not! We just need to grow up, he says, and embrace the underlying beauty of it. Some philosophers have accused Dennett of being the very thing he criticizes, a greedy reductionist. But this seems to be an unfair assessment of Dennett, especially in light of the fact that he yearns to see the magnificence within the natural world via evolution.

Section Two:

I loved the opening quote of this section: "Nothing make sense except in light of evolution" (Theodosius Dobzhansky). This quote sums up the theme of section two. The "Laws of the Game of Life" (i.e., biology which he calls engineering) can only be understood in terms of evolution. The laws and regularities we witness in nature really rely on blind, meaningless chaos. There is no Universal Mind or Wizard of Oz behind the curtain pulling the strings. Instead, the world we live in today is a result of what Crick called "frozen accidents." Sure, Paley witnessed design and he was right to. But design is the accumulation of billions of years of a mindless, algorithmic process. Nietzsche's Eternal Recurrence theme is placed in this section to stress the meaninglessness of life and the only meaning we find is that which we create ourselves.

I especially appreciate his discussion of "intellectual tennis" in section two. Defenders of Special Creation want to play "intellectual tennis" with the net down on their side when serving (referring to not following rules and not offering evidence) but up for the opponent. This is certainly unfair in the field of science.

Finally, Dennett exerts a lot of energy challenging Gould's perspective of evolution and science. He refers to Gould as the "boy who cried wolf" and even had references to him as a "bully." Why is Dennett so taken back by Gould? Well, quite simply, he accuses him of misrepresenting Darwinian evolution. While Gould brilliantly contributed the idea of spandrels to evolutionary theory, his resistance to gradualism, Dennett contends, is off putting. Other controversies, including Teilhard's Omega Point theory, are shot down in this part of the book.

Section Three:

The third section of the book starts with meme theory. Dawkins' memetic understanding of cultural evolution gets the thumbs up from Dennett. Language itself plays a crucial "crane" role in the development of the human mind, though Chomsky has resisted the interplay between Darwinian evolution and linguistics. Instead, Chomsky, along with Searle, contends Dennett, understands the mind more as a "skyhook" than a "crane," especially in both of their rejection of Artificial Intelligence as modeling human intelligence. Moreover, Penrose's meme of Godel's Theorem as proof against AI needs to be "extinguished," says Dennett.

Having highlighted the power of Darwin's dangerous idea still further, Dennett turns his attention to morality and evolution. Are sociobiologists being greedy reductionists by reducing morality to a product of evolution? Certainly, he petitions, we need to understand ethics along Darwinian lines but perhaps not to the level the greedy reductionist would take us. Here Dennett argues that we are not set creatures but that we have the "mind-tools to design and re-design ourselves" and even to re-design moral codes themselves.

In the conclusion of the book Dennett suggests that upon closer inspection Darwin's dangerous idea is not a "wolf in sheep's clothing," but a "friend mistaken as an enemy." Here he is referring to the famous story Beauty and the Beast. Instead of being a terrifying beast, Darwin's dangerous idea is really "a friend of Beauty, and indeed quite beautiful in its own right."

The Making of the Fittest *by Sean B. Carroll*

In this country we use DNA every day. We use it in the court system and crime scenes; we use it in paternity tests; etc. But, the author asks, why do fifty percent of Americans take issue with implications of DNA in understanding evolution? Since we have mapped out the entire human genome, our comprehension of DNA in the natural world has grown "40, 000 fold." Genomics, the study of DNA, simply overwhelms us with solid evidence of evolution, asserts Carroll.

The author goes to great length to demonstrate through several fascination examples evolution in the natural world. The icefish, a bloodless vertebrate, evolved as it did with the loss of hemoglobin in order to survive freezing temperatures of the Antarctic.

Thomas Huxley's "natural selection" (he was the first to coin the phrase) was certainly at work here. Carroll also offers us an example of how DNA itself clearly illustrates evolution. Fossil genes (namely, DNA left over from our ancestors) are found in all species throughout the world.

Referring to his book as "genocentric" (i.e., concentrating mostly on DNA), Carroll wrote *The Making of the Fittest* for the average layperson with the objective to explain how evolution works. The topic of evolution and the evidence of it need not be an erudite subject reserved for scientists, he says.

Carroll addresses several questions in his effort to clarify to the public what evolution is. For instance, he asks how often do mutations occur in nature? Are they the norm? Carroll walks us through the statistics on this. He explains that among 7 million DNA letters we experience about 175 mutations. But why don't we see mutations on the human species all the time? Most of the mutations occur on what is called "junk DNA," and this is not purged unless its effects are negative. Also, since we carry two copies of genes sometimes mutations do not show up on one gene. Despite all of this, the author refers to us as "all mutants." We are a product of these mutations. It is important to note that natural selection "rejects the changes that are harmful, favors changes that are beneficial, and is blind to changes that are neutral."

What is most fascinating is how many genes we have compared with other species. Homo sapiens possess around 25,000 genes. Many plants, mice and fish carry the same number. Even a worm has 20,000 genes. A fruit fly has two times the genes as yeast and a human has about two times the genes of a fruit fly. As complicated as humans are, why do we not possess more genes than other species? Interestingly, many of our genes are in fact redundant.

In this book we find out that evolution repeats itself many times over. What a great concept! Carroll gives several examples of how evolution does this. For instance, different species develop similar toxins or similar flippers or similar vision. Statistics illustrate that over the vast course of time and having had numerous offspring, "identical or equivalent mutations will arise repeatedly by chance."

The genome of any species contains "a record of the history of life." It holds information about not only its own species but also all the preceding species to the beginning of life on earth. There are about 500 immortal genes (or fossil genes) that all seem to share. The retaining of genes and losing of genes over time demonstrate that there is no concept of progress in evolution. Natural selection is not about design or intent. We are not better adapted than other species of the past. We are just different. William Paley's design arguments falters when one considers, as Darwin did, that vast amounts of time of gradual and sometimes rapid change explains the rich variety of life forms we see today without invoking the notion of a designer.

The anti-evolution movement is lead by the religious right who do not understand genetics and the power of DNA research in proving evolution at play. Creationists do not understand the connection between randomness at the DNA level and natural selection. The author takes great effort to clarify that natural selection does not entail randomness at all. As he says it, "selection, which is not random, determines what chance occurrences are retained." Cumulative selection over eons of time produce the rich tapestry of the organic matter we see today. Evolution is simply the interplay of "chance and necessity." Moreover, Creationists do not understand what a scientific theory entails. It is not an educated guess but "a well substantiated explanation of some aspect of the natural work that can incorporate facts, laws, inferences, and tested hypothesis." The evidence for evolution is overwhelming and it cannot be argued away. There are indeed religious minded people, such as Pope John Paul and the scientist Kenneth Miller, who embrace evolution as factual.

Quoting Peter Medawar, "the alternative to thinking in evolutionary terms is not to think at all." This, Carroll purports, is something we as a species cannot afford. In fact, Carroll ends his book with a chapter on how not understanding evolution has led and will continue to lead to enormous gaffes on the part of humans in nature. Our actions have resulted in destroying balanced ecosystems but it is our responsibility to understand and respect the dynamics of nature. Over-fishing has depleted the waters of certain species of fish; pollution has contributed to the warming of the oceans; many animals are near extinction at our hands. There is no more time to debate the fact of evolution as we destroy elements of this planet. Two centuries of detailed science has moved evolution from the hypothesis stage to the scientific theory stage (that which is supported by a variety of facts, not the least of which is DNA). It is time to wake up and take responsibility, even if out of self-interest, as he put it.

Dawkins vs. Gould: Survival of the Fittest *by Kim Stefelny*

This book examines the commonalities and, more importantly, major differences between Dawkins and Gould on the theory of evolution.

Let us begin by looking at what they have in common:

Evolution occurred 4 billion years ago.

The process was natural, not divine.

Chance plays a role.

There is no aim, no purpose.

There is nothing inevitable about humans.

Variation in populations leads to varying reproductive chances.

Natural Selection is essential for evolution: the more fit in the environment has more descendents.

Natural Selection for humans works slowly over generations but fast for short term organisms.

Large, random changes are mostly disasters since change must be gradual and cumulative; but on occasion and very rarely there is one big mutation. Overall, though, evolution is generally a long series of small changes.

Differences between Dawkins and Gould abound as well; both represent totally different traditions in evolutionary biology. The focus of this book is on these main differences:

Dawkins vs. Gould:

Dawkins: Dawkins looks at ethology and problems of adaptation.

Gould: Gould, on the other hand, is a paleontologist who studies fossils; he sees himself as a historian of life.

Dawkins vs. Gould:

Dawkins: Dawkins focuses on evolution as a history of gene lineages where there are long periods of small changes. Genes replicate almost identical to predecessor. Struggle of evolution is struggle of genes to replicate. Yes, this is reductionistic but genes make the organism.

Gould: Gould instead concentrates on extinction and not persistence of gene lineages. He looks at the basic blueprint of animals noting that there are no fundamental new inventions. Gould argues that chance is more important and genes less important. Luck plays a role he says and not just fitness. Catastrophes happen, he points out, and the lucky survive, not the fit.

Dawkins vs. Gould:

Dawkins: Dawkins carries a different attitude about science than Gould. He is the son of enlightenment who looks at science as the best way to gain knowledge. Science is complete and beautiful, he says; it is open to revision with new evidence and new ideas. Finally, Dawkins argues that science is not to be understood as "the dominate ideology of the time but engine of objective knowledge."

Gould: Gould, on the other hand, views science as not complete; there are social influences on scientific views (his book *Mismeasure of Man* illustrated this). Basically, he argues that the ideology of the time impacts science.

Dawkins vs. Gould:

Dawkins: Dawkins' views on religion vary from Gould's; he is an atheist and sees religion with no authority on values. Religion, he asserts, is a meme, and a destructive one at that. He goes as far as to call religion a virus that we need to get rid of.

Gould: Gould argues that science and religion are different domains. Science does not study moral claims where religion does, he states. Gould does not address theism questions though and seems to avoid them altogether. Also, Gould does not support postmodern relativism.

Dawkins vs. Gould:

Dawkins: Dawkins supports evolutionary psychology – the using of evolution to understand our behavior; he argues that this is a liberating idea since it liberates us from religion.

Gould: Gould does not like evolutionary psychology / socio-biology; he argues that it is a dangerous idea that can justify heinous acts like rape.

Dawkins vs. Gould:

Dawkins: Dawkins argues for natural selection acting on genes/gene lineages, Adaptation, quips Dawkins, evolves slowly in small steps with occasional large changes; overtime there is a large range of variation possible.

Gould: One the other end, Gould focuses on natural selection on organisms and not genes per se; Gould argues that evolutionary possibilities are constrained since they are basically entrenched.

Overall, this was a fascinating read on how two respected scientists in the field of evolution can so drastically disagree. What this illustrates, to me, is that science is not a dogmatic discipline but a healthy one full of lively debates that keep inching us along to a more accurate understand of how the world works.

Why Darwin Matters *by Michael Shermer*

Shermer argues, rightfully so, that the ID movement is mainly a front for creationism. He examines the history of this topic from the Scope's trial to the recent Dover trial. Overall, this reading is a superb source to understand the problems with the ID movement.

There are a variety of problems with the ID movement. Here is a list of some of the major problems Shermer addresses:

1. The ID movement is a front for a religious position.

2. The Second Law of Thermodynamics is misunderstood.

3. Either – or – Fallacy (accept God as Designer or accept total chaos) is prevalent in the ID movement.

4. The burden of proof falls on claimant and extraordinary claims require tons of proof.

5. The ID movement argues that randomness does not produce the world or apparent design in nature; however, they do not understand that randomness actually builds on itself and so quite significant results can happen rapidly.

6. There are multiple creation accounts in the world and there should not be equal time.

Shermer addresses key questions of evolution. Here are some important queries:

1. Can you believe in god and evolution? His answer: Yes. He uses the NOMA argument of Gould.

2. Should the conservative Christians embrace evolution? Yes. Science need not contradict religion. He uses the Pope John Paul example to show that science and religion can work together.

3. Why do we see design? Because we are designed to see a Designer!

4. Why is there a shortage of fossils? It is rare to find a fossil since animals in past were eaten as a general rule; however, there are plenty of intermediate forms available today.

The author highlights the evidence of evolution. The following are some examples of the evidence he covers:

1. Dawkins' *Ancestor's Tale* is one of the best compilations of evidence.

2. The concept of scientific "theory" is misunderstood; a theory really it is a fact supported by all of the natural sciences and evolution has earned this title.

3. Grant's work on finches, a twenty year study, verifies Darwin's data.

Shermer discusses strange designs in nature that evolution explains:

1. Males have a form of a uterus off the prostrate gland.

2. Males also have nipples.

3. Just as apes have a 13th rib so do 8% of humans.

4. Humans have a tailbone.

5. We have an appendix for digesting cellulose (primal diet was mostly vegetarian).

6. Strangely, we have goose bumps and these resemble the raising of animal fur.

In the Epilogue, Shermer's final comments match Chet Raymo's work that the scientific world view does not diminish spirituality or beauty in the world. Science can foster a feeling of spirituality as one feels connected to an infinite universe and "moved to tears" from scientific revelations. Attempting to illustrate how amazing this multi-universe is, Shermer coins a new term he calls "sciensuality, meaning a feeling of awe, humility and sensuality of discovery." Science tells us the story about "who we are, where we come from and where we are going." Thus, he says, Darwin indeed matters.

In the final section of the book, the Appendix, Shermer discusses Eugenie Scott's argument that there are at least 8 different religious views on the creation-evolution issue; these are the following:

1. Young earth creationism

2. Old earth creationism

3. Gap creationism

4. Day-age creationism

5. Progressive creationism

6. ID creationism

7. Evolutionist creationism

8. Theistic evolution

Darwin Loves You *by George Levine*

The title of this book, *Darwin Loves You*, is a take-off of the "Jesus loves you" bumper sticker. But instead of a Christian premise, Levine illustrates that Darwin's research radically enchants the world with a sense of wonder and awe in nature. Much like Chet Raymo's thesis in *Skeptic and True Believers*, Levine illustrates that Darwin, and science itself, does not in any way de-mystify the world. Rather, scientific research such as Darwin's is able to mystify the world as we are left dumbfounded by the awesome revelations it reveals. Specifically, the *Origin of Species* gives us an appreciation for how amazing nature is.

Throughout the text the author counters Max Weber's position (as well as William James') that science, following the rational school of thought, disenchants the world and creates a world void of meaning and value. Instead, Levine makes the case that Darwin serves as a model for what Shermer calls "sciensuality." While religion tends to devalue the world, Darwin, argues Levine, offers us a new view. Thus, Weber has it backwards: science is not the one that demystifies the world but religion does. Science offers us a healthy view by explaining the world naturalistically with a deep connection to nature.

Darwin ennobles the earth, he explains clearly, and Weber was simply wrong. In fact, Darwin, through his work, offers "spiritual, cultural, and ethical value." Yet, Levine is talking about a non-theistic enchantment, a wonderment experienced by understanding the world materialistically and naturalistically. For Darwin, matter was not inert or meaningless but alive and vibrant.

Even Darwin's son, William, contended that for his father religion was in nature, and this insight offered religious feelings of awe. More accurately put, science can offer us life with "moments of enchantment." But the author was quick to clarify that moments of enchantment was not necessarily an enchanted life, just glimpse of the magnificence of nature.

Though we live in a wonderful world full of awe, beauty and mystery, it can still be a scary and dangerous place filled with bombs, rapes, slaughters, pain, as John S. Mill pointed out. While science does not justify pain, through science one can explain it. More importantly, the enchantment idea can offer us a reprieve from the pain. For instance, understanding how the eye works via evolution is magnificent and may lessen a feeling of being overpowered by nature and its unexpected turns.

This insight also parallels the "love the earth, our home" theme of Nietzsche when he petitions us to love the world despite the hardships and pains because this earth is our home and all we have and really know. The Ubermensch has the courage to face the world as it is and emerge transformed.

For the author sociobiology and evolutionary psychology are too reductionistic for his taste and contribute, he says, to disenchantment of humans. Just like the 19th century Victorians, scientists such as Pinker, Dawkins and Dennett fit in the reductionistic, positivistic camp. Darwin, while he embraces reductionism, argues Levine, does not fit in the exact same school of thought. Instead, he practices what the author calls "good reductionism" and not "greedy reductionism" or bad science. Levine even places Edward O. Wilson, the author of *Consilience,* in this radical reductionistic group for explaining humans via genetics. Levine concedes that Wilson has some romantic elements in his consilience theory but enchantment is lost when everything in the natural world is reduced to scientific law.

According to Levine, the affect of awe that Dennett and others miss is found throughout the *Origins of Species*, almost with "exclamation points." (Note: having read Dennett's work I am not sure this is a fair assessment of him.) What Darwin saw that amazed him, that offered richness and wonder in nature, was the incredible understanding that we are all related, that all of nature is connected. Humans lose their anthropocentric position but in place of it we become part of the greater whole. Epictetus' message of interconnectedness dominates.

There are two more key points that Levine addresses: Darwin was affiliated with biases of his cultural times but in no way does this diminish the validity of his work. And the author looks at the misuse of Darwinian theory to justify social, political aims (e.g., Social Darwianism). He defends Darwin despite abuses of his theory by others because an "is" does not imply an "ought," as Hume brilliantly posited.

The Reluctant Mr. Darwin *by David Quanmmen*

A wonderful and insightful biography on the life of Darwin, this book focuses on Darwin's life post the Beagle adventure and it makes clear his internal struggle to publish his masterpiece, *Origins of Species.* Several factors contributed to the delay of publishing it: major physical ailments; family tragedies like the death of two children; and, probably most significant, a fear of society's backlash.

In terms of Darwin's religious background, he was raised both secular and a liberal Christian. The reason he first attended theology school to become a parson was because such a profession allowed him, after the Sunday obligations, the rest of the week to pursue a life as a naturalist. Darwin eventually rejected this career as his theism waned. His theistic perspective was followed by deism and then eventual secular materialism. However, elements of theism are still found in the *Origin of Species*, published in 1859, when he refers to the Creator. Darwin even quotes William Whewell's "Divine Power" idea as the creator of "general laws."

But is Darwin truly a theist? No. He sees too many questions in nature that forces him to ask: why would a benevolent god create so much cruelty and chaos in nature? Examples of nature's frenzy include the laying of wasp eggs inside a caterpillar so that the larva could eat the host upon hatching. Even the death (most likely from tuberculosis) of his favorite and oldest child, Annie, shows the "problem of evil" that Darwin never seems to reconcile.

The author brilliantly argues that Darwin does not really challenge the existence of god as he does the godliness of man. By this saying this, Darwin is concentrating on the interconnectedness of all of nature, of all life forms, and the humans do not stand apart from or above it. Darwin refers to this interconnection as the "grandeur of life."

This grandeur is clearly illustrated when we compare the human genome with that of a mouse's. The 30,000 genes that we both have are 99% direct "counterparts" (meaning very similar but not identical as a chimp and a humans are). Life is from one original source. Embryology shows that we have signs in the embryo state of the progenitor before (e.g., tail, gills, body hair, etc.)

Biogeography, a field that deals with the spread of animal and plant distribution on the planet, was of particular interest to Darwin. He was fascinated with how life forms can be spread across the world. Seeds survive in animal feces and are passed to other areas. Clams hook on to water bettle's legs and as they catch a ride develop habitat elsewhere. Interestingly, the last clam/bettle specimen Darwin was given came from the grandfather of Francis Crick.

What was Wallace's role in this field? He sent Darwin a manuscript detailing his evolution ideas that included transmutation and natural selection (the latter was not coined by Wallace) prior to the publishing of *Origin of Species.* Darwin, along with his scientist friends, decided to give Wallace co-recognition in a paper at a science lecture on the topic. Darwin then was given the impetus to overcome his prior reluctance, fearing that someone would gain priority in the field. The *Origins of the Species* shortly followed, selling out of first edition copies on the first day of sales. Both scholars argued for gradualism and against

Lamarkianism, but later on Wallace, a supporter of spiritualism, argued that natural selection could not account for the development of the human brain. Darwin refers to Wallace's slip into spiritualism as intellectual suicide.

Overall, this book was quite an enjoyable biography. It offers insights to Darwin's personal life that make his scientific endeavors even more impressive.

The Ancestor's Tale *by Richard Dawkins*

Dawkins begins his tale by explaining that humans are pattern, meaning seeking creatures. Being the pattern seeking creatures that we are, humans look at the history of the world and believe that it was fine-tuned to bring humanity into existence (basically, this is the anthropic principle). He refers to this as the "conceit of hindsight." Our conceit is the belief that the past works to deliver the present, namely us, and so humans are the final goal in evolutionary history.

But is evolution progressive? No, argues Dawkins, not at all. We are wrong to think that our predecessors were transitional beings and a halfway mark to us. The idea of us being "more evolved," however, comes from an incorrect, human centric perspective. Dawkins humorously points out that if elephants could write history they would see everything as leading up to the development of the trunk.

This text takes a different approach to understanding evolutionary theory. Instead of starting with the earliest forms and showing the diversity of life, Dawkins goes backwards, beginning with humans, to show the unity of life. This backward approach traces humans back to a shared ancestor with the apes, more than 18 million years ago and eventually back to the progenitor of all, the bacterium. The point of a shared ancestor, the moment of a rendezvous of a last common ancestor, is called a "concestor." Is there a concestor of all life forms? Yes, since we share a common genetic code with all of life on this planet. The Grand Concestor of all life forms, bacterial fossils, dates 3.5 billion years ago.

Dawkins adventure begins with the Homo sapiens as he pilgrimages from the present to the past common ancestor. On our journey the first pilgrims we meet are the chimps 5 million years ago. This is followed by the gorillas, then the orangutans, to the gibbons, to the old world monkeys, then to other mammals and eventually to the first form in the sea.

There are only 40 rendezvous points in the human pilgrimage to the origin of life. In other words, there are 40 steps or 40 concestors in our history to the first life form. Concestor number 39 is the grand ancestor of all life forms. These 40 natural milestones is a literary allusion to Chaucer's Canterbury reference of a pilgrim's tale.

Dawkins points out three main methods to understanding evolution: archeology (hard relics such as fossils, etc.); renewed relics such as DNA; triangulation, that is, triangulating an ancestor by comparing two surviving descendents. Let us look at each of these briefly:

1. Fossils: fossils demonstrate evolution but even if there are gaps in the fossil records there is overwhelming evidence of evolution; fossils are just a bonus.

2. DNA: the alphabet of DNA is a like a writing system that records and copies. DNA changes very slowly so the record is woven into all plants and animals. Four letters allows for 64 limited words. There is a 64 word DNA dictionary that is universal and unchanging. DNA, argues Dawkins, is the genetic book of the dead, a chronicle of the past.

3. Triangulation: this is the comparison of DNA sequences of species and a look for shared DNA; for instance, comparing human and bacteria DNA to find overlap and resemblances. An analogy would be a similarity of languages like German and Dutch. But human and chimp DNA is so similar it is like English spoken in two slightly different accents but still English nonetheless. The analogy continues when you compare English and Japanese---there are no two organisms that can compare to the great differences between these two languages, not even humans and bacteria. All of this shows a definite family tree among organisms.

The actual pilgrimage now begins. If we look at the first tens of thousands of years (say 50,000 years ago) there really is no genetic difference than we are today. There are two major cultural advances in the last 50,000 years: agricultural revolution (farmer) and Cro-Magnon's tale (the flowering of the human mind). The farmer's tale was an agrio-revolution that began 10,000 years ago at the end of the last ice age and is called the new stone age or Neolithic. There is a transition from the hunter-gatherer and a new idea of home. At this time large populations are supported but diseases are now a threat; domestication, farming and urban life are central. This period was preceded by what Dawkins calls the cro-magnon tale. It began 40,000 years ago as the hunter-gather society was dominant with music, figurines, graves, paintings, carvings, etc. There was no longer a million year stagnation but the flowering of consciousness in the

Homo sapiens; some even attribute this to the origin of language.

Dawkins speaks a great deal about concestor 0. But what is concestor 0? It is the most recent ancestor of all surviving humans. MRCA refers to the most recent common ancestor. Mitochondrial DNA MRCA is called mitochondrial Eve; for males the MRCA is called y-chromosome Adam. Adam and Eve could actually be separated by tens of thousands of years; Eve most likely preceded Adam; she was probably 140,000 years ago and Adam 60,000 years ago.

Rendezvous 0 refers to tens of thousands of years ago to hundreds of thousand at most. And Rendezvous 1 refers to the fork between humans and chimps millions of years ago. Dawkins makes an interesting claim that you may be more related genetically to a chimp than to some humans. One big difference between humans and chimps, though, is the FOXP2 gene. This FOXP2 gene is the gene that allows humans to have language. Since chimps lack this gene they also lack language as we have.

An interesting question is: are we related to the Neanderthals? And is there interbreeding between Neanderthal and humans? Most likely the answer to both of these is no since mitochondrial Eve does not match them; few if any genes of ours come from them.

Homo ergaster or Homo erectus lived one million years ago. And actually they were no more erect than predecessor Homo habilis. They are altogether a different species than us. Moreover, it is not conclusive if they used fires but there is some evidence of campfires; tools were used and we are not sure if they had developed some form of language.

Homo habilis lived two million years ago and are referred to as the Habilines. What is unique about them? These handymen from Africa had larger brains; 750 cc brain was significant since the larger brain now fits the homo category. The Autralopithecus was its predecessor.

The brain size of the Homo sapien is 6 times larger than it should be for a typical mammal of equivalent size. The Homo habilis is about 4.5 times bigger than it should be and a Homo erectus is about 4 times larger. For a chimp its brain is about 2 times larger than it should be for a mammal that size. What accounts for the EQ (encephalisation quotient) of humans? There are various theories that Dawkins considers. Certainly, it is our brain size that makes us a bit unique but in no way superior.

Australopithecus afraenis lived 3.2 million years ago; Lucy, a bipedal being, is an example of this found in Ethiopia in 1974. Why the rise to bipedal? There are numerous theories; these include: having extra height to see; squat feeding to turn over rocks looking for insects; freeing of hands to carry food; having less sun on the body. Dawkins argues that there may be several factors that account for it. Little Foot is a 4 million year old bipedal fossil whose toes also suggests tree climbing too.

Overall, the *Ancestor's Tale* is an essential read to further one's knowledge on the subject of evolution. Michael Shermer, in *Why Darwin Matters*, goes as far as to call the book one of the greatest compilations on evolution ever. And certainly I agree.

The Human Genome Sourcebook *by Tara Acharya and Neeraja Sankaran*

This textbook is essentially a summary of the 1990s Human Genome Project, also referred to as the "Book of Life," or the "blueprint" or "recipe book." The recipe is the genome, derived from the words gene and chromosome.

While the *Human Genome Sourcebook* was written with the general reader in mind, it is still scientifically challenging. The authors refer to their work as a reference volume and certainly that is what it is. This reference text begins with a historical overview of heredity beginning with Lamark's, Darwin's and Mendel's research. It then continues to give a history of genetics. In the early 1900s William Bateson coined the term "genetics," referring to genesis of traits. Some of the first genetic research on chromosomes began with Thomas Morgan's work on fruit flies at Columbia University in the early 1900s.

Here is some of the information catalogued within the text:

DNA inside each cell, if stretched out, would be over 6 feet long.

Chromosomes vary with each species: while humans have 23 pairs, a peanut has 20, a dog has 39 and a sugar cane has 40 pairs.

The entire human genome consists of 3.1 billion base pairs.

The text highlights the numerous ethical concerns regarding genetic research, namely genetic profiling and eugenics.

A large portion of this book is dedicated to defining genetic terms and concepts from genotype to mitochondrial DNA. An understanding of chromosomes and genetic diseases follows the term section. Cancer, diabetes, lupus and the like are genetically explained.

While reading the text my focus was on evolution: correctly explained was the idea that apes or monkeys did not give rise to humans, but that we share a common ancestor with them. The authors clarified that evolution occurs at a slower rate the larger the genome size. Our 3 billion base pairs results in a slower rate of change than species with a smaller number of base pairs.

While not per se entertaining, one learns a lot within the pages and so it was, overall, a worthwhile read.

DNA: The Secret of Life *by James Watson*

James Watson, co-founder of the structure of the DNA molecule, begins with a discussion of the origins of genetics. Interestingly, he points out that it really began with the Greeks, including Hippocrates. Pangenesis (the transfer of miniature parts of the body via sperm/egg) was a popular idea of the time. Even Darwin entertained pangenesis to explain inheritance, since he was unaware of Mendel's breakthrough research on genetics. Pangenesis idea was finally decimated when amputated tailless mice kept producing offspring with tails. As in the *Human Genome Sourcebook*, Morgan's research on fruit flies was discussed; fruit flies make a great specimen since a new generation only takes ten days and a female lays hundreds of eggs.

Francis Galton in the 19th century introduced eugenics, meaning "good in birth." Even George Bernard Shaw referred to eugenics as that which "can save our civilization." There were two approaches: Galton's positive eugenics that encouraged gifted people to procreation; and negative eugenics that tried to prevent those viewed as not superior from reproducing. The IQ test in the early 20th century contributed to a fear that bad genes were entering American soil. Henry Goddard argued that immigrants were the cause of the downward spiral of American intelligence. Theodore Roosevelt bought the argument. Sadly, racism, while not inherent to eugenics, became connected to it. Hitler became part of the movement as well.

Watson retells the story of how he and Crick discovered the structure of the DNA molecule. One competitor scientist was Rosalind Franklin, who died at 37 of ovarian cancer. Feb. 28th, 1953 marks the day the discovery was made. Vitalism was put to an end at this time. Soon after the discovery of the structure of the DNA molecule, evidence of genetic mutation was conclusively demonstrated. Usually A and T matched up and C and G matched up; but on occasion there was a genetic mix up and the sequence changed.

Several interesting chapters, such as the ones on biotechnology and genetically modified agriculture, followed the explanation of the DNA structure. The human genome project receives special attention.

My favorite section was chapter nine on DNA and evolution where our human past is examined. Homo neanderthalensis can be dated 30,000 years ago and are described as a different yet similar species to our own. They had slightly larger brains and there is evidence they buried the dead and may have believed in an afterlife. DNA solved the mystery of our relations to them. When one scientist working on the DNA sequencing referred to the excitement as "something starting to crawl up my spine" I was reminded of Chet Raymo's argument that good science produces a "shudder up the spine."

Strangely, it turns out that we were more closely related to Neanderthal than to chimpanzees and so Neanderthals are considered part of the human tree (a branch but not part of the same limb). However, we do not see Neanderthal genes mixed with ours so interbreeding is suspect. While we are genetically different than the Neanderthal, this research indicates how connected we are overall with the natural world.

One question that caught my attention was: at what point did the human lineage separate from the chimps and gorillas? Mary-Claire King's research indicated it occurred no more than 5 million years ago. And she also showed that humans and chimps differed genetically only by 1%. Gorillas and chimps differ by 3%. So we are closer to chimps than they are to gorillas.

Watson clarifies that the ancestor of all humans arose in Africa. And, interestingly, we can trace a common ancestor to all humans no more than 150,000 years ago.

Humans are almost genetically identical with each other. We are 99.9% alike. Variation among humans is very little compared with other species. Fruit flies are 10X more variant and chimps are 3X more variant. Why are humans so alike, Watson asks? He argues it is because our common ancestor was so recent, only 150,000 years ago, and this was "insufficient time for substantial variation to arise through mutation."

Watson makes the claim that under the fur of a chimp their skin is white. And that since we were connected to them genetically with a common ancestor 5 million years ago, black skin pigmentation later arose in human evolution to protect African skin from damaging sun rays (certainly necessary without as much body hair).

Though we are only 1% genetically different than chimps this is enough to account for enormous phenotype differences. For instance, we have language and they do not. The gene to account for why humans developed language and chimps did not is called the FOXP2 gene.

Near the book's end there is an important section on Edward O. Wilson's work on evolutionary psychology. Watson argues that Wilson's pivotal 1975 work should move from the "fringes of anthropology to the very heart of the discipline."

And, finally, Watson concludes his book was an argument for human genetic enhancement. But this idea has sometimes received a harsh reception, as it did when it was presented in Germany several years ago. Watson understands the ethical implication of this but hopes for a world with less disease and pain.

This reading reveals the wonderful awesomeness of DNA and a world so intimately connected through it. James Watson deserves applause for illuminating the "secret of life."

Nature Revealed: Selected Writings 1949-2006 *by Edward O. Wilson*

Edward O. Wilson compiled some of his classic work into this masterpiece. Highlighting the history of sociobiology, Wilson also spotlights a better integrated science known as "consilience." Both of these topics are indeed powerful tools to "reveal nature." Let us look at sociobiology and consilience separately:

Sociobiology:

Interestingly, Wilson's work began in 1949 with the study of fire ants. One question he asked was: Why is there a sterile caste in ants? He discovered that the unit of natural selection is the family unit and not the individual. Sterile ants work as helpers to serve reproductive interests of the family unit. Furthermore, his study of ants revealed that ants occupy the land for 100 million years. One form of social adaptation is slavery. Ants raid nests and make captives slaves.

Moreover, Wilson's work on ants led him to study pheromones. When pheromones where discovered in animals, Wilson's study of ants invisible odor served as strong evidence of these hormones. In 1963 there is the first notion of these hormones in humans.

In 1975 Wilson completed *Sociobiology: The New Synthesis*. While sociobiology was applied to animals in 1971, it was now applied to humans four years later. This new discipline eventually led to evolutionary psychology.

Evolutionary psychology shows that human decency / altruism arises from genes favoring them. Moral philosophy or ethics, as well as religion, can be explained with biology. Furthermore, Wilson explores the link between genetic evolution and cultural evolution....from genes to neural, mental development to mind to culture.

Wilson notes that there is a misunderstanding about sociobiology: it is not a belief that human behavior is genetically determined. But, according to Wilson, it is: "the study of the biological basis of all forms of social behavior in all organisms."

In 1980 Wilson focuses on global conservation movement and he becomes one of the fathers of this movement. One of his biggest fears is the loss of biological diversity as a result of humans. However, when discussing conservation ethics, he explains that biophilia is our natural affinity for life and our innately emotional affiliation with other organisms. Wilson points out that 99% of human history was hunter-gatherer bands and they were so intimately involved with life and organisms. Thus, the brain evolved, he argues, as biocentric.

Consilience:

Wilson's work on consilience work began in 1998. It is an attempt to connect natural science with social science/humanities. The term means "jumping together" of different fields of study. He refers to it as an "integrated science," where various disciplines are interlocked and reducible to the same general laws of nature.

The author dates the true origins of consilience with Thales of the 6th century BCE who appeared to be interested in a common network of explanations. With consilience, complex biological phenomena are reducible to the simple. For instance, biology can be explained in part by chemistry, which is in part can be explained by physics and then by quantum physics.

In today's age, there is now a connection between the natural science and the social sciences: neuroscience, psychology, philosophy are intertwined. Neural activity explains consciousness and consciousness explains culture. Thus, the mind has a "reducible material basis." Wilson argues that the social science will advance with consilience as it takes the reductionistic approach to human nature.

Now it can be argued that genetic evolution is linked directly to cultural evolution. Epigenetic rules determined by neurology / brain states established cross cultural universals (such as taboos against incest, fear of snakes, etc.)

Integrated science produces winners all around as it illustrates causally linked phenomena. There need not be distinct branches of learning but each is strengthened by assimilation. Overall, Wilson points out the obvious causal links between genes, mind and culture. As we are baffled by the meaning of our existence, an integrated understanding of the world is indeed necessary. Thanks to Wilson's seminal work, "nature is revealed" through this line of thinking.

Appendix: The Descent of Man

Selected excerpts from Charles Darwin's Book

All that we know about savages, or may infer from their traditions and from old monuments, the history of which is quite forgotten by the present inhabitants, shew that from the remotest times successful tribes have supplanted other tribes. Relics of extinct or forgotten tribes have been discovered throughout the civilised regions of the earth, on the wild plains of America, and on the isolated islands in the Pacific Ocean. At the present day civilised nations are everywhere supplanting barbarous nations, excepting where the climate opposes a deadly barrier; and they succeed mainly, though not exclusively, through their arts, which are the products of the intellect. It is, therefore, highly probable that with mankind the intellectual faculties have been mainly and gradually perfected through natural selection; and this conclusion is sufficient for our purpose. Undoubtedly it would be interesting to trace the development of each separate faculty from the state in which it exists in the lower animals to that in which it exists in man; but neither my ability nor knowledge permits the attempt.

It deserves notice that, as soon as the progenitors of man became social (and this probably occurred at a very early period), the principle of imitation, and reason, and experience would have increased, and much modified the intellectual powers in a way, of which we see only traces in the lower animals. Apes are much given to imitation, as are the lowest savages; and the simple fact previously referred to, that after a time no animal can be caught in the same place by the same sort of trap, shews that animals learn by experience, and imitate the caution of others. Now, if some one man in a tribe, more sagacious than the others, invented a new snare or weapon, or other means of attack or defence, the plainest self-interest, without the assistance of much reasoning power, would prompt the other members to imitate him; and all would thus profit. The habitual practice of each new art must likewise in some slight degree strengthen the intellect. If the new invention were an important one, the tribe would increase in number, spread, and supplant other tribes. In a tribe thus rendered more numerous there would always be a rather greater chance of the birth of other superior and inventive members. If such men left children to inherit their mental superiority, the chance of the birth of still more ingenious members would be somewhat better, and in a very small tribe decidedly better. Even if they left no children, the tribe would still include their blood-relations; and it has been ascertained by agriculturists287 that by preserving and breeding from the family of an animal, which when slaughtered was found to be valuable, the desired character has been obtained.

Turning now to the social and moral faculties. In order that primeval men, or the apelike progenitors of man, should become social, they must have acquired the same instinctive feelings, which impel other animals to live in a body; and they no doubt exhibited the same general disposition. They would have felt uneasy when separated from their comrades, for whom they would have felt some degree of love; they would have warned each other of danger, and have given mutual aid in attack or defence. All this implies some degree of sympathy, fidelity, and courage. Such social qualities, the paramount importance of which to the lower animals is disputed by no one, were no doubt acquired by the progenitors of man in a similar manner, namely, through natural selection, aided by inherited habit. When two tribes of primeval man, living in the same country, came into competition, if (other circumstances being equal) the one tribe included a great number of courageous, sympathetic and faithful members, who were always ready to warn each other of danger, to aid and defend each other, this tribe would succeed better and conquer the other. Let it be borne in mind how all-important in the never-ceasing wars of savages, fidelity and courage must be. The advantage which disciplined soldiers have over undisciplined hordes follows chiefly from the confidence which each man feels in his comrades. Obedience, as Mr. Bagehot has well shewn, is of the highest value, for any form of government is better than none. Selfish and contentious people will not cohere, and without coherence nothing can be effected. A tribe rich in the above qualities would spread and be victorious over other tribes: but in the course of time it would, judging from all past history, be in its turn overcome by some other tribe still more highly endowed. Thus the social and moral qualities would tend slowly to advance and be diffused throughout the world.

But it may be asked, how within the limits of the same tribe did a large number of members first become endowed with these social and moral qualities, and how was the standard of excellence raised? It is extremely doubtful whether the offspring of the more sympathetic and benevolent parents, or of those who were the most faithful to their comrades, would be reared in greater numbers than the children of selfish and treacherous parents belonging to the same tribe. He who was ready to sacrifice his life, as many a savage has been, rather than betray his comrades, would often leave no offspring to inherit his noble nature. The bravest men, who were always willing to come to the front in war, and who freely risked their lives for others, would on an average perish in larger numbers than other men. Therefore, it hardly seems probable that the number of men gifted with such virtues, or that the standard of their excellence, could be increased through natural selection, that is, by the survival of the fittest; for we are not here speaking of one tribe being victorious over another.

Although the circumstances, leading to an increase in the number of those thus endowed within the same tribe, are too complex to be clearly followed out, we can trace some of the probable steps. In the first place, as the reasoning powers and foresight of the members became improved, each man would soon learn that if he aided his fellow-men, he would commonly receive aid in return. From this low motive he might acquire the habit of aiding his fellows; and the habit of performing benevolent actions certainly strengthens the feeling of sympathy which gives the first impulse to benevolent actions. Habits, moreover, followed during many generations probably tend to be inherited.

But another and much more powerful stimulus to the development of the social virtues, is afforded by the praise and the blame of our fellow-men. To the instinct of sympathy, as we have already seen, it is primarily due, that we habitually bestow both praises and blame on others, whilst we love the former and dread the latter when applied to ourselves; and this instinct no doubt was originally acquired, like all the other social instincts, through natural selection. At how early a period the progenitors of man in the course of their development, became capable of feeling and being impelled by, the praise or blame of their fellow-creatures, we cannot of course say. But it appears that even dogs appreciate encouragement, praise, and blame. The rudest savages feel the sentiment of glory, as they clearly show by preserving the trophies of their prowess, by their habit of excessive boasting, and even by the extreme care which they take of their personal appearance and decorations; for unless they regarded the opinion of their comrades, such habits would be senseless.

They certainly feel shame at the breach of some of their lesser rules, and apparently remorse, as shewn by the case of the Australian who grew thin and could not rest from having delayed to murder some other woman, so as to propitiate his dead wife's spirit. Though I have not met with any other recorded case, it is scarcely credible that a savage, who will sacrifice his life rather than betray his tribe, or one who will deliver himself up as a prisoner rather than break his parole, would not feel remorse in his inmost soul, if he had failed in a duty, which he held sacred.

We may therefore conclude that primeval man, at a very remote period, was influenced by the praise and blame of his fellows. It is obvious, that the members of the same tribe would approve of conduct which appeared to them to be for the general good, and would reprobate that which appeared evil. To do good unto others—to do unto others as ye would they should do unto you—is the foundation-stone of morality. It is, therefore, hardly possible to exaggerate the importance during rude times of the love of praise and the dread of blame. A man who was not impelled by any deep, instinctive feeling, to sacrifice his life for the good of others, yet was roused to such actions by a sense of glory, would by his example excite the same wish for glory in other men, and would strengthen by exercise the noble feeling of admiration. He might thus do far more good to his tribe than by begetting offspring with a tendency to inherit his own high character.

With increased experience and reason, man perceives the more remote consequences of his actions, and the self-regarding virtues, such as temperance, chastity, &c., which during early times are, as we have before seen, utterly disregarded, come to be highly esteemed or even held sacred. I need not, however, repeat what I have said on this head in the fourth chapter. Ultimately our moral sense or conscience becomes a highly complex sentiment—originating in the social instincts, largely guided by the approbation of our fellow-men, ruled by reason, self-interest, and in later times by deep religious feelings, and confirmed by instruction and habit.

It must not be forgotten that although a high standard of morality gives but a slight or no advantage to each individual man and his children over the other men of the same tribe, yet that an increase in the number of well-endowed men and an advancement in the standard of morality will certainly give an immense advantage to one tribe over another. A tribe including many members who, from possessing in a high degree the spirit of patriotism, fidelity, obedience, courage, and sympathy, were always ready to aid one another, and to sacrifice themselves for the common good, would be victorious over most other tribes; and this would be natural selection. At all times throughout the world tribes have supplanted other tribes; and as morality is one important element in their success, the standard of morality and the number of well-endowed men will thus everywhere tend to rise and increase.

It is, however, very difficult to form any judgment why one particular tribe and not another has been successful and has risen in the scale of civilisation. Many savages are in the same condition as when first discovered several centuries ago. As Mr. Bagehot has remarked, we are apt to look at the progress as normal in human society; but history refutes this. The ancients did not even entertain the idea, nor do the Oriental nations at the present day. According to another high authority, Sir Henry Maine, "The greatest part of mankind has never shewn a particle of desire that its civil institutions should be improved."290 Progress seems to depend on many concurrent favourable conditions, far too complex to be followed out. But it has often been remarked, that a cool climate, from leading to industry and to the various arts, has been highly favourable thereto. The Esquimaux, pressed by hard necessity, have succeeded in many ingenious inventions, but their climate has been too severe for continued progress. Nomadic habits, whether over wide plains, or through the dense forests of the tropics, or along the shores of the sea, have in every case been highly detrimental. Whilst observing the barbarous inhabitants of Tierra del Fuego, it struck me that the possession of some property, a fixed abode, and the union of many families under a chief, were the indispensable requisites for civilisation. Such habits almost necessitate the cultivation of the ground and the first steps in cultivation would probably result, as I have elsewhere shewn,291(2) from some such accident as the seeds of a fruit-tree falling on a heap of refuse, and producing an unusually fine variety. The problem, however, of the first advance of savages towards civilisation is at present much too difficult to be solved.

With savages, the weak in body or mind are soon eliminated; and those that survive commonly exhibit a vigorous state of health. We civilised men, on the other hand, do our utmost to check the process of elimination; we build asylums for the imbecile, the maimed, and the sick; we institute poor-laws; and our medical men exert their utmost skill to save the life of every one to the last moment. There is reason to believe that vaccination has preserved thousands, who from a weak constitution would formerly have succumbed to small-pox. Thus the weak members of civilised societies propagate their kind. No one who has attended to the breeding of domestic animals will doubt that this must be highly injurious to the race of man. It is surprising how soon a want of care, or care wrongly directed, leads to the degeneration of a domestic race; but excepting in the case of man himself, hardly any one is so ignorant as to allow his worst animals to breed.

The aid which we feel impelled to give to the helpless is mainly an incidental result of the instinct of sympathy, which was originally acquired as part of the social instincts, but subsequently rendered, in the manner previously indicated, more tender and more widely diffused. Nor could we check our sympathy, even at the urging of hard reason, without deterioration in the noblest part of our nature. The surgeon may harden himself whilst performing an operation, for he knows that he is acting for the good of his patient; but if we were intentionally to neglect the weak and helpless, it could only be for a contingent benefit, with an overwhelming present evil. We must therefore bear the undoubtedly bad effects of the weak surviving and propagating their kind; but there appears to be at least one check in steady action, namely that the weaker and inferior members of society do not marry so freely as the sound; and this check might be indefinitely increased by the weak in body or mind refraining from marriage, though this is more to be hoped for than expected.

In every country in which a large standing army is kept up, the finest young men are taken by the conscription or are enlisted. They are thus exposed to early death during war, are often tempted into vice, and are prevented from marrying during the prime of life. On the other hand the shorter and feebler men, with poor constitutions, are left at home, and consequently have a much better chance of marrying and propagating their kind.

Man accumulates property and bequeaths it to his children, so that the children of the rich have an advantage over the poor in the race for success, independently of bodily or mental superiority. On the other hand, the children of parents who are short-lived, and are therefore on an average deficient in health and vigour, come into their property sooner than other children, and will be likely to marry earlier, and leave a larger number of offspring to inherit their inferior constitutions. But the inheritance of property by itself is very far from an evil; for without the accumulation of capital the arts could not progress; and it is chiefly through their power that the civilised races have extended, and are now everywhere extending their range, so as to take the place of the lower races. Nor does the moderate accumulation of wealth interfere with the process of selection. When a poor man becomes moderately rich, his children enter trades or professions in which there is struggle enough, so that the able in body and mind succeed best. The presence of a body of well-instructed men, who have not to labour for their daily bread, is important to a degree which cannot be over-estimated; as all high intellectual work is carried on by them, and on such work, material progress of all kinds mainly depends, not to mention other and higher advantages. No doubt wealth when very great tends to convert men into useless drones, but their number is never large; and some degree of elimination here occurs, for we daily see rich men, who happen to be fools or profligate, squandering away their wealth.

Primogeniture with entailed estates is a more direct evil, though it may formerly have been a great advantage by the creation of a dominant class, and any government is better than none. Most eldest sons, though they may be weak in body or mind, marry, whilst the younger sons, however superior in these respects, do not so generally marry. Nor can worthless eldest sons with entailed estates squander their wealth. But here, as elsewhere, the relations of civilised life are so complex that some compensatory checks intervene. The men who are rich through primogeniture are able to select generation after generation the more beautiful and charming women; and these must generally be healthy in body and active in mind. The evil consequences, such as they may be, of the continued preservation of the same line of descent, without any selection, are checked by men of rank always wishing to increase their wealth and power; and this they effect by marrying heiresses. But the daughters of parents who have produced single children, are themselves, as Mr. Galton295 has shewn, apt to be sterile; and thus noble families are continually cut off in the direct line, and their wealth flows into some side channel; but unfortunately this channel is not determined by superiority of any kind.

Although civilisation thus checks in many ways the action of natural selection, it apparently favours the better development of the body, by means of good food and the freedom from occasional hardships. This may be inferred from civilised men having been found, wherever compared, to be physically stronger than savages. They appear also to have equal powers of endurance, as has been proved in many adventurous expeditions. Even the great luxury of the rich can be but little detrimental; for the expectation of life of our aristocracy, at all ages and of both sexes, is very little inferior to that of healthy English lives in the lower classes.

In regard to the moral qualities, some elimination of the worst dispositions is always in progress even in the most civilised nations. Malefactors are executed, or imprisoned for long periods, so that they cannot freely transmit their bad qualities. Melancholic and insane persons are confined, or commit suicide. Violent and quarrelsome men often come to a bloody end. The restless who will not follow any steady occupation—and this relic of barbarism is a great check to civilisation— emigrate to newly-settled countries; where they prove useful pioneers. Intemperance is so highly destructive, that the expectation of life of the intemperate, at the age of thirty for instance, is only 13.8 years; whilst for the rural labourers of England at the same age it is 40.59 years. Profligate women bear few children, and profligate men rarely marry; both suffer from disease. In the breeding of domestic animals, the elimination of those individuals, though few in number, which are in any marked manner inferior, is by no means an unimportant element towards success. This especially holds good with injurious characters which tend to reappear through reversion, such as blackness in sheep; and with mankind some of the worst dispositions, which occasionally without any assignable cause make their appearance in families, may perhaps be reversions to a savage state, from which we are not removed by very many generations. This view seems indeed recognised in the common expression that such men are the black sheep of the family.

Natural selection follows from the struggle for existence; and this from a rapid rate of increase. It is impossible not to regret bitterly, but whether wisely is another question, the rate at which man tends to increase; for this leads in barbarous tribes to infanticide and many other evils, and in civilised nations to abject poverty, celibacy, and to the late marriages of the prudent. But as man suffers from the same physical evils as the lower animals, he has no right to expect an immunity from the evils consequent on the struggle for existence. Had he not been subjected during primeval times to natural selection, assuredly he would never have attained to his present rank. Since we see in many parts of the world enormous areas of the most fertile land capable of supporting numerous happy homes, but peopled only by a few wandering savages, it might be argued that the struggle for existence had not been sufficiently severe to force man upwards to his highest standard. Judging from all that we know of man and the lower animals, there has always been sufficient variability in their intellectual and moral faculties, for a steady advance through natural selection. No doubt such advance demands many favourable concurrent circumstances; but it may well be doubted whether the most favourable would have sufficed, had not the rate of increase been rapid, and the consequent struggle for existence extremely severe. It even appears from what we see, for instance, in parts of S. America, that a people which may be called civilised, such as the Spanish settlers, is liable to become indolent and to retrograde, when the conditions of life are very easy. With highly civilised nations continued progress depends in a subordinate degree on natural selection; for such nations do not supplant and exterminate one another as do savage tribes. Nevertheless the more intelligent members within the same community will succeed better in the long run than the inferior, and leave a more numerous progeny,

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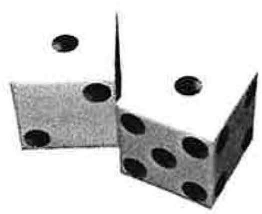
Monograph 2

SPOOKY PHYSICS:

Einstein vs. Bohr

Spooky Physics

Einstein vs. Bohr



Andrea Diem-Lane

Spooky Physics

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Mt. San Antonio College, Walnut

To my husband, David

Table of Contents

Introduction: An Age-Old Problem

What is truly real? And how do we know? These twin questions, sometimes related in philosophical jargon to ontology and epistemology, are of central importance in understanding the dramatic implications of quantum theory. Indeed, one could argue that the reason quantum theory is so baffling to understand is because it upends our deepest and most cherished ideas about what is real and what is not. Moreover, quantum theory calls into question the very process of how we know things. It is for this reason that Albert Einstein resisted the implications of quantum theory because he knew that what it portended was an end to determinism and an end to a strict causality governing the universe. Of course, for others like Niels Bohr, succumbing to such indeterminism, even if intellectually disagreeable, is precisely what the theory demands. In other words, it is indeterminism itself which informs all of quantum theory, and to neglect that marked characteristic is to ignore its most vital feature.

Einstein ultimately found the implications of quantum theory so unsettling that he made a number of terse remarks on it. In a letter to Max Born, dated September 1944, he wrote, "You believe in the God who plays dice, and I in complete law and order in a world which objectively exists, and which I, in a wildly speculative way, am trying to capture. I hope that someone will discover a more realistic way, or rather a more tangible basis than it has been my lot to find. Even the great initial success of the Quantum Theory does not make me believe in the fundamental dice-game…." In fact, Einstein spent a good sum of his life trying to come up with thought experiments which would demonstrate the incompleteness of quantum theory and show why it was at best an interregnum theory which would in time yield to a more reasonable and deterministic one. As he quipped to Born, "Although I am well aware that our younger colleagues interpret this as a consequence of senility. No doubt the day will come when we will see whose instinctive attitude was the correct one."

This book is a brief introduction to the famous Einstein-Bohr debate over the implications of quantum theory with a special focus on the philosophical ramifications of Heisenberg's uncertainty principle. We are fortunate that there exists a fairly extensive record of the conversations between these two eminent thinkers. Indeed, it isn't hyperbolic to call the Einstein-Bohr conflict one of the greatest intellectual debates of modern times, nay of any time period.

This book begins with an overview of quantum theory and its early development. It also explores some of its weirder aspects, including the dual aspect of light quanta. In Chapter two, we explore why Einstein found many aspects of quantum theory so disagreeable, especially the idea of uncertainty relations where knowing an electron's position increases the ignorance of knowing an electron's momentum, and vice versa. Chapter three centers on why Bohr accepted quantum indeterminism (what he called complimentarity) and encouraged his colleagues and students (such as Pauli and Born and Heisenberg) to play out its consequences to the fullest—what would later be famously called the Copenhagen school. The most heated section of the book comes in Chapter four where we get to witness (both through transcriptions of talks given at the time and through extensive correspondence, particularly the letters to and from Max Born) the passion of Einstein's arguments against quantum theory and Bohr's equal passion for it. Although both Bohr and Einstein have been dead for decades, Chapter five illustrates that their debate still lives on and why it is still a very hot topic even among a newer generation of physicists. And, finally, in the conclusion we ask what this debate means for us and our day to day lives.

Our evolution has bounded what we can and cannot know about the world around us. Because of this our brains are not well adapted to understand either the very large or the very small. We are quite literally middling creatures that have been shaped for eons of time to survive in eco-niches where our food and prey are accessible to our five apertures. What this means, of course, is that whenever we venture beyond our middle earth by extending our senses to the very large or very small, we have to acclimate ourselves anew.

The history of science is a record of how humans achieved such acclimations and how, in turn, such new insights transformed our understanding of how the universe actually works. Whether it was Galileo's telescope (seeing a pock marked moon versus a polished lunar surface) or Copernicus mathematical equations (indicating a solar based orbital system versus an earth centered one), in each case sensory or mental breakthroughs led to revolutions in scientific thought. It may be no exaggeration to say that whenever we altered our bodily or cranial limits we extended our world, a world which is forever linked to the limitations of what the senses can and cannot reveal.

To say that neurology is ontology is merely to state the obvious. But what sometimes gets lost in such clichés is that our brain state is never static and thus the world is never the same as well. Change the neural apparatus and one transforms the universe. Not necessarily because the brain creates such realities, but rather because the limitations of one's cranial capacities predetermines what is accessible or knowable about any given aspect of reality. Change those neural coordinates and thereby change one's intellectual map.

All of this is necessary preface to understand why the human mind has an almost innate difficulty in understanding quantum theory—a theory which takes into account things so infinitesimally tiny that even our best analogies freeze our minds in a state of wonder.

Ludwig Wittgenstein gives us a fruitful glimpse of just how contradictory quantum physics can be and why it demonstrates prima facie its almost inherent illogical nature. Writing several years before the discovery of Werner Heisenberg's Nobel Prize winning discovery of the uncertainty relations in the subatomic realm, Wittgenstein states in his famous *Tractatus Logico-Philosophicus*:

> 6.3751: For two colours, e.g. to be at one place in the visual field, is impossible, logical impossible, for it is excluded by the logical structure of colour. Let us consider how this contradiction presents itself in physics. Somewhat as follows: That a particle cannot at the same time have two velocities, i.e. that at the same time it cannot be in two places, i.e. that particles in different places at the same time cannot be identical. It is clear that the logical product of two elementary propositions can neither be a tautology nor a contradiction. The assertion that a point in the visual field has two different colours at the same time is a contradiction.

Today, of course, quantum physicists state the opposite of Wittgenstein's logical necessity about the behavior of matter and point out that indeed a particle can be in two places at the same time, even if that space and time is limited in its regional and temporal import.

Spooky Physics

What Wittgenstein captured (quite unwittingly since his Tractatus dates from the latter part of the First World War) was how a rational, logical mind would be upended by the implications of quantum theory. Moreover, he provides us with a framework for why it may be so difficult for many of us to actually "get" quantum theory. As Richard Feynman, the well-known architect behind Quantum Electrodynamics (QED), once quipped, "I think I can safely say that nobody understands quantum mechanics."

I can think of no better caveat than Feynman's when approaching this most profound of subjects. Listening in on the Einstein-Bohr debate may not resolve our own existential dilemmas, but it will undoubtedly put into sharp relief what is at stake when confronting the heart of matter itself.

Chapter One: Quantum Weirdness

Imagine taking a road trip to Las Vegas, Nevada, from Huntington Beach, California. Depending on the traffic, and how fast one is driving, it may take anywhere from five to eight hours. However, there are sections along the way (particularly near Barstow) where speeding too fast will most likely result in being stopped by the highway patrol and receiving a ticket. This can happen even when there appears to be no law enforcement officers in sight.

Why? Because of sophisticated radar tracking stations that monitor traffic flow. Radio waves emitted from the station spread out in varying directions and when they hit a moving object, some of those waves bounce back and are received again at the tracking station, containing two key pieces of information: the position of the vehicle and its momentum. This may seem a bit trivial but these forms of information are absolutely vital to understanding almost anything in the physical universe. Indeed, one can exaggerate here a bit and say almost all of physics is based on these two points of data. Knowing only the position of the car, for instance ("hey, there's a Ford truck in Duarte"), isn't sufficient to warrant a speeding ticket. And if one only knows the momentum of the vehicle but not its whereabouts it is a bit frustrating.

Now this fairly trite example can be applied to almost any event in our day to day lives, from when to attend a lecture at the local college, to when we pick up our children from elementary school, to when we pick up pizza at our neighborhood restaurant. The civilized world is fundamentally based on knowing both the position and momentum of physical objects, including when and where to pick up our spouses from shopping at Target.

Newtonian physics is a picture of this mechanistic and predictable universe and, as such, serves us well in navigating our lives through most events. However, when we begin to look at bits of matter that are extraordinarily small, this same guiding map breaks down.

Imagine now that instead of taking a car to Las Vegas, you are riding on a single electron (to slightly butcher Einstein's more famous metaphor of riding on a beam of light), traveling much faster than the speed limit of 70 miles per hour. Indeed, you would be approaching the ultimate speed that any particle can travel, 186,000 miles per second. Clearly, such speeding warrants a ticket! But, in this instance, the electron police find themselves in a very strange conundrum. Because what they discover to their chagrin is that the more they comprehend how fast the electron is traveling the less they know about where it is exactly located. And, then, when they do get a fix on its position, they lose sight of its momentum.

What they soon realize is that their very act of measuring is interfering with the electron's ultimate position and/or momentum. It is as if the radar itself (which is in truth nothing more than electromagnetic energy) is literally moving the electron at different speeds and/or in different directions.

This is akin to being in a car and having the radar either bump up your speed a hundred miles an hour or having it transport you to another freeway and sending you on your way to San Diego. Something is clearly wrong with this picture. Something is clearly breaking down. And if this happened in our wayward drives to cities in the desert, the highway patrol's radar tracking station would be directly responsible for our speeding violations or for our confused and haphazard sojourns. One could literally say to the ticketing patrolman, "But you made me speed and/or switch lanes. Therefore, you should be giving yourself the ticket, not me." And, given what we know about how the radar interfered with your car, the judge would be forced to admit the obvious and let you off and reprimand the traffic station.

Enter the weird and twisted world of quantum mechanics. While our car example only becomes viable at the level of the very small, it is disconcerting nonetheless to realize that Newtonian physics breaks down precisely when one gets closer to the secrets of Nature. In order to understand why uncertainty increases when we explore the very small, we need to first understand what Max Planck discovered over a century ago when studying black body radiation.

Instead of radiant energy being emitted purely in waves and in smaller and smaller frequencies which could be halved ad infinitum, Planck theorized (though apparently he thought that his views would be only a temporary bridge) that energy came in discrete packets, quantified bits of matters, known more popularly later as "quanta." Quanta cannot be halved, and thus electromagnetic energy can only come in multiples of this basic unity of energy, later known famously as Planck's constant.

This is analogous to when one goes to the store to buy a bottle of classic coke. Let's say the 20 ounce bottle costs one dollar and twenty-nine cents (the current price at our local 7/11) and you give the clerk 2 bucks. Now imagine when you get your change of 71 cents that you object to the penny and argue that you want something "smaller" than the penny, like 1/10 of a cent or even a ½ of a cent. The clerk will no doubt look at you a bit strange and he or she may reply, "But we have nothing less than a penny. That's the lowest amount of money available."

You cannot "halve" a penny in our day to day world. Likewise, you cannot halve a quanta. Nature, it seems, has decided that the smallest unit for exchange is this single photon and apparently there is no way around this. You literally cannot "short" change nature, even if your physicist's intuition suggests that you should be able to. Of course Planck's constant is indeed very small, 6.626068 × 10-34 m2 kg / s.

So small, in fact, that our minds cannot really grasp, except with faulty analogies and metaphors, the tininess of the subatomic realm. The implications of the quantification of matter was not lost on Albert Einstein who used Planck's understanding to develop his theory on the photo-electric effect for which he eventually won his only Nobel Prize.

What was so disconcerting about Planck's discovery (or, should we say unintended uncovering) and Einstein's photoelectric effect was that for decades physicists had experimentally demonstrated that light acted like a wave, but now there was evidence of its particle-like nature. This dualistic realization about the nature of matter forced the world of science into a theoretic crises. How can it be both? Or, as the experiments at the time indicated, how is it that in one context light propagates as if it was a wave and in another context light behaves as if it were composed of tiny bullets? Is nature so capricious?

Moreover, if light is both a wave and a particle why is it that only one aspect (but not both) shows up in varying experimental designs? Do we really choose how light is going to behave?

The famous double slit experiment illustrates very clearly the inherent weirdness of the quanta world. Richard Feynman, the famous Nobel Prize winning physicist of the 1960s, has stated that analyzing this experiment alone can reveal the deep mysteries of quantum mechanics.

There have been a large number of books (and even a few films) which have explained how the double slit experiment works. It was first devised by Thomas Young in the early part of the 19th century in which he devised an obstacle with two openings and passed a beam of light through the apertures which would then hit an adjoining barrier wall. What he found was that when light passed through these two slits it caused an interference pattern showing that light had a wave light aspect. However, later experiments showed that if you only had one slit open, light acted as a discrete packet (a quanta) which demonstrated that it had a particle or bullet like aspect.

How the light behaves depends on how the experiment is set-up. Open up just one slit and light acts like a particle. Open up two slits and light acts like a wave. But, the real question (and the one at the heart of quantum weirdness) is how does the light know if the other slit is open or closed? Even if only one photon is allowed to pass through only one slit, if the other slit is open it will act like a wave. If, however, the other slit is closed, the light will be particle like.

Andrew Zimmerman Jones does a brilliant job of explaining the double slit experiment and why it is so mysterious:

> It became possible to have a light source that was set up so that it emitted one photon at a time. This would be, literally, like hurling microscopic ball bearings through the slits. By setting up a

screen that was sensitive enough to detect a single photon, you could determine whether there were or were not interference patterns in this case.

One way to do this is to have a sensitive film set up and run the experiment over a period of time, then look at the film to see what the pattern of light on the screen is. Just such an experiment was performed and, in fact, it matched Young's version identically - alternating light and dark bands, seemingly resulting from wave interference.

This result both confirms and bewilders the wave theory. In this case, photons are being emitted individually. There is literally no way for wave interference to take place, because each photon can only go through a single slit at a time. But the wave interference is observed. How is this possible? Well, the attempt to answer that question has spawned many intriguing interpretations of quantum physics, from the Copenhagen interpretation to the many-worlds interpretation.

Now assume that you conduct the same experiment, with one change. You place a detector that can tell whether or not the photon passes through a given slit. If we know the photon passes through one slit, then it cannot pass through the other slit to interfere with itself.

It turns out that when you add the detector, the bands disappear! You perform the exact same experiment, but only add a simple measurement at an earlier phase, and the result of the experiment changes drastically.

Something about the act of measuring which slit is used removed the wave element completely. At this point, the photons acted exactly as we'd expect a particle to behave. The very uncertainty in position is related, somehow, to the manifestation of wave effects.

As we will see later on, how one interprets this experiment will have deep philosophical repercussions.

What determines light as a wave or a particle is dependent (literally) on our measuring device. And even then we cannot know both the momentum and position of that particle/wave with absolute precision. For instance, the more we know about the electron's position, the less we know about its momentum, and vice versa.

Werner Heisenberg, whose name is forever attached with this discovery (thus we have "Heisenberg's uncertainty principle") realized to the ultimate consternation of Einstein that this indeterminism forced physicists to take a different approach when trying to resolve the quanta's secrets. Instead of an exact causal explanation of any singular electron dance, what was needed was a probabilistic model of how the electron or any subatomic material behaved. It is as if nature itself was a gambling device and what it paid out was determined by odds.

The glitch, of course, for any would-be gambler (or should we say any would-be quantum mechanic) is that he or she never actually knows in one throw of the dice or one pull of the slot lever whether one is going to win or lose.

How to get around this impasse? How to beat the odds? Well, you can't actually in one throw or one pull, but you can if you gamble enough.

For instance, take a coin toss. It is either going to be heads or tails, but never both if you let it land on the ground (and not, in the very rare occasion, on its side). The odds are 50/50 which can also be translated as "I don't know." That it will be one or the other allows you some ultimate outcome that you can guess but never absolutely know in one isolated toss of the coin.

However, if you are allowed to toss the coin many times (a thousand or more times, for instance), then something else comes into play: probability functions. That is, the more you toss the coin the more you start to see patterns emerge which, given the science of statistics, will provide you with a fairly accurate gauge of what you can expect to see if one is allowed to toss a coin a million times.

A good example of this is drawn right from Las Vegas casinos (hopefully, your car has reached there by now without too much interference). The casino does not know whether or not you are going to win at the poker slot machine when you put in your dollar. Indeed, if the gambling establishment is genuine and not rigged, then it CANNOT know precisely. However, since the casino makes significant amounts of money the question arises very simply: How can that be possible if it is due to chance only? The answer is both simple and profound. Yes, the casino does not know in advance what "dice" the gambler is going to throw down on the craps table in any one isolated event, but it does have a very good understanding of the probable odds of how many winners and losers it will get if the game is played enough. This is, of course, the science of statistics.

For instance, if you toss a quarter, there is a 50/50 chance you will get heads or tails. The odds are evenly split. However, if you toss that same coin say 1000 times, you will start to see a certain pattern emerge. You will quickly notice how difficult it is to get 200 heads in a row or 500 tails in a row. You will start to be able to calculate the odds of certain patterns emerging or not emerging. These odds, or mathematical probabilities, will start to give you some "certainty" even when dealing with something fundamentally uncertain.

So, if a friend of mine wants to bet me that she can get a 100 heads in a row, the next question I must ask her is "how many times are you going to throw it.?" Because the number of throws will either increase or lessen my confidence in taking up her bet. If she says, ah, give me a thousand tries, I would easily take her up on the bet. If, however, she starts to talk about a trillion times a trillion times, I wouldn't venture such a wager.

Quantum mechanics is essentially a probabilistic model to provide us with how an uncertain realm can yield quite predictable, even if occasionally quite odd, outcomes and trajectories.

This leads, however, to all sorts of strange and unusual paradoxes. A recent cover story on quantum theory in the *New Scientist* by Gregory T. Huang has posited four very famous illustrations of quantum weirdness:

Schrödinger's cat

Conventional quantum theory says that particles can be in a superposition of two states at once. This leads to the thought experiment of a cat being both alive and dead inside a box, depending on the state of a toxic subatomic particle. Only when you open the box or make a measurement is the animal's fate determined.

Spooky action at a distance

Einstein decried the idea of entanglement - that one particle could instantaneously affect another's spin, say, through a weird quantum link. This phenomenon, also known as non-locality, has since been demonstrated and is a key principle behind quantum computers and communications.

Objective reality

Does the moon exist if nobody is looking at it? Conventional quantum theory says there is no reality beyond what we observe, so in principle things don't exist unless they are being measured.

Uncertainty principle

If you measure the position of a quantum particle, you can't know its momentum precisely, and vice versa. The conventional explanation is that there is randomness inherent in the quantum universe.

Einstein realized that quantum theory gave astounding results and predictions, but he never felt comfortable with it as a final theory. He felt something was amiss and that at best quantum theory was an interregnum theory and that in time realism and not indeterminism would reign once again. Turning now to chapter two let's discover why Albert Einstein felt that God didn't play dice with the universe and its ultimate governing laws.

Chapter Two: Einstein Doesn't Play Dice

"I think that a 'particle' must have a separate reality independent of the measurements. That is an electron has spin, location and so forth even when it is not being measured. I like to think that the moon is there even if I am not looking at it."

"Thus the last and most successful creation of theoretical physics, namely quantum mechanics (QM), differs fundamentally from both Newton's mechanics, and Maxwell's e-m field. For the quantities which figure in QM's laws make no claim to describe physical reality itself, but only probabilities of the occurrence of a physical reality that we have in view."

"I cannot but confess that I attach only a transitory importance to this interpretation. I still believe in the possibility of a model of reality - that is to say, of a theory which represents things themselves and not merely the probability of their occurrence. On the other hand, it seems to me certain that we must give up the idea of complete localization of the particle in a theoretical model. This seems to me the permanent upshot of Heisenberg's principle of uncertainty."

--*Albert Einstein*

What is it about quantum theory that so troubled Einstein that he would spend nearly a quarter of his life trying to find a replacement for it?

The answer is perhaps a bit simpler than we might suspect. Einstein was a realist and believed in an objective universe that exists outside of our subjective observations of it. What so bothered Einstein about quantum theory (even though he contributed to it with his photoelectric effect and Brownian motion papers and appreciated its many strengths) was that it was inherently probabilistic and that at its philosophic and methodological core was an uncertainty principle which pointed to the variability of human measurement. As John Wheeler, the eminent physicist at Cornell and Princeton and the University of Texas at Austin, later stated, "There is no phenomena unless it is an observed phenomena."

This was intolerable to Einstein since as he suggested to his eventual biographer and physics colleague, Abraham Pais, the moon really does exist even when I don't look at it.

Einstein's objections to quantum theory took two major turns. First, almost from the outset, Einstein attempted to show how the new quantum mechanics as defined by Heisenberg and Bohr was mistaken. Later, Einstein accepted to some measure the correctness of quantum theory, but tried to point out how it was an incomplete theory and most likely a bridge theory to something much more comprehensive and complete.

One of the key sticking points for Einstein was the breakdown of individual causality inherent in quantum theory, where a measuring device a priori determines the outcome of a quantum state. As Joshua Roebke in "The Reality Tests" points out,

> Schrodinger and Heisenberg independently uncovered dual descriptions of particles and atoms. Later, the theories proved equivalent. Then in 1926 Heisenberg's previous advisor, Max Born, discovered why no one had found a physical interpretation for Schrodinger's wave function. They are not physical waves at all; rather the wave function includes all the possible states of a system. Before a measurement those states exist in superposition, wherein every possible outcome is described at the same time. Superposition is one of the defining qualities of quantum mechanics

and implies that individual events cannot be predicted; only the probability of an experimental outcome can be derived. (Seed, volume 16).

The fact that quantum theory involves a connection between a measuring device and how we can ascertain reality was, for Einstein, fundamentally problematic. In a famous letter to Max Born, dated March 3, 1947, Einstein outlines why:

> I cannot make a case for my attitude in physics which you would consider at all reasonable. I admit, of course, that there is a considerable amount of validity in the statistical approach which you were the first to recognize clearly as necessary given the framework of the existing formalism. I cannot seriously believe in it because the theory cannot be reconciled with the idea that physics should represent a reality in time and space, free from spooky actions at a distance. I am, however, not yet firmly convinced that it can really be achieved with a continuous field theory, although I have discovered a possible way of doing this which so far seems quite reasonable. The calculation difficulties are so great that I will be biting the dust long before I myself can be fully convinced of it. But I am quite convinced that someone will eventually come up with a theory whose objects, connected by laws, are not probabilities but considered facts, as used to be taken for granted until quite recently. I cannot, however, base this conviction on logical reasons, but can only produce my little finger as witness, that is, I offer no authority which would be able to command any kind of respect outside of my own hand.

Perhaps the key line in the above referenced letter by Einstein is this: "I cannot seriously believe in it because the theory cannot be reconciled with the idea that physics should represent a reality in space and time, free from spooky actions at a distance."

What reality was Einstein presupposing here? An external world freed from human measurement—a world which exists truly and clearly apart from human subjectivity. But, as Einstein rightly surmised, this objective world collapses with

Heisenberg's uncertainty principle, since external reality at its most fundamental constituency (atoms) is absolutely unknowable, except through a measuring device which in and of itself alters what is known. In other words, quantum mechanics is a statement about reality itself and what it is saying is that there is no world "out there" apart from our observations of it. Our observations, in other words, are part and parcel of what we observe. The dualistic idea of a world apart from our selves is a fiction. For Einstein this was the very antithesis of science in general and physics in particular. The whole scientific enterprise was predicated on the notion of an external world which was independent of the machinations of the subjective participants that arose within it.

But the real culprit here in Einstein's mind is the introduction of probability and statistics as a final pathway for understanding the underlying laws of subatomic materials. While Einstein readily concedes the powerful utility of Born's statistical understanding of wave matrices, his "little finger" tells him that quantum mechanics is merely a prelude to a greater and more unified theory which will eventually transcend probability functions and yield a straightforward and causal and objective explanation of how and why matter behaves the way it does.

As Einstein near the end of his life pointed out, "It seems to be clear, therefore, that Born's statistical interpretation of quantum theory is the only possible one. The wave function does not in any way describe a state which could be that of a single system; it relates rather to many systems, to an 'ensemble of systems' in the sense of statistical mechanics."

Further he elaborates on why he finds the statistical method a transitory one:

> Thus the last and most successful creation of theoretical physics, namely quantum mechanics (QM), differs fundamentally from both Newton's mechanics, and Maxwell's e-m field. For the quantities which figure in QM's laws make no claim to describe physical reality itself, but only probabilities of the occurrence of a physical reality that we have in view.... I cannot but confess that I attach only a transitory importance to this interpretation. I still believe in the possibility of a model of reality - that is to say, of a theory which represents things themselves and not merely the probability of their occurrence. On the other hand, it seems to me certain that we must give up the idea of complete localization of the particle in a theoretical model. This seems to me the permanent upshot of Heisenberg's principle of uncertainty.

Why was Einstein so recalcitrant to a theory which measured only probabilities, especially if those very probabilities led to amazingly exact results? Some scholars have suggested that Einstein stubbornness was due to his personal psychology which looked for an order that he didn't see in the world of human affairs. Or, perhaps it stemmed from Einstein's first epiphany as a young boy at the age of eleven where he was able to prove for himself Pythagoras' theorem.

Along this line of reasoning, it has been argued that Einstein's passion in science was fueled by his even greater passion for discovering a truth apart from human artifice. In any case, whatever personal motivations lie behind Einstein's resistance to a purely statistical interpretation of physics, it is unassailable that he also found it philosophical objectionable. One of Einstein's more pregnant, even if cryptic, remarks about human ideas and reality is captured in his January 27th 1921 lecture to the Prussian Academy of Sciences in Berlin, Germany:

> At this point an enigma presents itself which in all ages has agitated inquiring minds. How can it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality? Is human reason, then, without experience, merely by taking thought, able to fathom the properties of real things. In my opinion the answer to this question is, briefly, this:—As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.

There are many ways to interpret what Einstein actually means here, especially in light of its philosophic import. But I think it presents a clearer beacon into why Einstein would have resisted a purely mathematical interpretation of physics, as was presented several years later by Born, Heisenberg, Bohr, et. al., in their formulation of quantum mechanics.

Einstein, ever being the realist, understood that human concepts were in themselves limited in their import and thus to conflate a theory in its present state for the ultimate state of reality was not only mistaken but wholly naïve. Ironically, in this sense, Einstein was a metaphysician whose "little finger" or "intuition" pointed beyond mere empiricism.

But Einstein's metaphysic wasn't of a religious or a spiritual kind, but rather for a reality that literally transcends human cognition and which forever escapes human thought to entrap it. As Einstein explained in his lengthy analysis of Bertrand Russell's theory of knowledge:

> In the evolution of philosophical thought through the centuries the following question has played a major role: what knowledge is pure thought able to supply independently of sense percep-

tion? Is there any such knowledge? If not, what precisely is the relation between our knowledge and the raw material furnished by sense impressions?

There has been an increasing skepticism concerning every attempt by means of pure thought to learn something about the 'objective world', about the world of 'things' in contrast to the world of 'concepts and ideas'. During philosophy's childhood it was rather generally believed that it is possible to find everything which can be known by means of mere reflection. It was an illusion which anyone can easily understand if, for a moment, he dismisses what he has learned from later philosophy and from natural science; he will not be surprised to find that Plato ascribed a higher reality to 'ideas' than to empirically experienceable things. Even in Spinoza and as late as in Hegel this prejudice was the vitalising force which seems still to have played the major role.

The more aristocratic illusion concerning the unlimited penetrative power of thought has as its counterpart the more plebeian illusion of naive realism, according to which things 'are' as they are perceived by us through our senses. This illusion dominates the daily life of men and of animals; it is also the point of departure in all of the sciences, especially of the natural sciences.

As Russell wrote;

'We all start from naive realism, i.e., the doctrine that things are what they seem. We think that grass is green, that stones are hard, and that snow is cold. But physics assures us that the greenness of grass, the hardness of stones, and the coldness of snow are not the greenness, hardness, and coldness that we know in our own experience, but something very different. The observer, when he seems to himself to be observing a stone, is really, if physics is to be believed, observing the effects of the stone upon himself.'

Gradually the conviction gained recognition that all knowledge about things is exclusively a working-over of the raw material furnished by the senses. Galileo and Hume first upheld this principle with full clarity and decisiveness. Hume saw that concepts which we must regard as essential, such as, for example, causal connection, cannot be gained from material given to us by the senses. This insight led him to a skeptical attitude as concerns knowledge of any kind.

Man has an intense desire for assured knowledge. That is why Hume's clear message seemed crushing: the sensory raw material, the only source of our knowledge, through habit may lead us to belief and expectation but not to the knowledge and still less to the understanding of lawful relations.

Then Kant took the stage with an idea which, though certainly untenable in the form in which he put it, signified a step towards the solution of Hume's dilemma: whatever in knowledge is of empirical origin is never certain. If, therefore, we have definitely assured knowledge, it must be grounded in reason itself. This is held to be the case, for example, in the propositions of geometry and the principles of causality.

These and certain other types of knowledge are, so to speak, a part of the implements of thinking and therefore do not previously have to be gained from sense data (i.e. they are a priori knowledge).

Today everyone knows, of course, that the mentioned concepts contain nothing of the certainty, of the inherent necessity, which Kant had attributed to them. The following, however, appears to me to be correct in Kant's statement of the problem: in thinking we use with a certain right, concepts to which there is no access from the materials of sensory experience, if the situation is viewed from the logical point of view. As a matter of fact, I am convinced that even much more is to be asserted: the concepts which arise in our thought and in our linguistic expressions are all- when viewed logically- the free creations of thought which cannot inductively be gained from sense experiences. This is not so easily noticed only because we have the habit of combining certain concepts and conceptual relations (propositions) so definitely with certain sense experiences that we do not become conscious of the gulf- logically unbridgeable- which separates the world of sensory experiences from the world of concepts and propositions. Thus, for example, the series of integers is obviously an invention of the human mind, a self-created tool which simplifies the ordering of certain sensory experiences. But there is no way in which this concept could be made to grow, as it were, directly out of sense experiences.

As soon as one is at home in Hume's critique one is easily led to believe that all those concepts and propositions which cannot be deduced from the sensory raw material are, on account of their 'metaphysical' character, to be removed from thinking. For all thought acquires material content only through its relationship with that sensory material. This latter proposition I take to be entirely true; but I hold the prescription for thinking which is grounded on this proposition to be false. For this claim- if only carried through consistently- absolutely excludes thinking of any kind as 'metaphysical'.

In order that thinking might not degenerate into 'metaphysics', or into empty talk, it is only necessary that enough propositions of the conceptual system be firmly enough connected with sensory experiences and that the conceptual system, in view of its task of ordering and surveying sense experience, should show as much unity and parsimony as possible. Beyond that, however, the 'system' is (as regards logic) a free play with symbols according to (logically) arbitrarily given rules of the game. All this applies as much (and in the same manner) to the thinking in daily life as to the more consciously and systematically constructed thinking in the sciences.

By his clear critique Hume did not only advance philosophy in a decisive way but also- though through no fault of his- created a danger for philosophy in that, following his critique, a fateful 'fear of metaphysics' arose which has come to be a malady of contemporary empiricist philosophising; this malady is the counterpart to that earlier philosophising in the clouds, which thought it could neglect and dispense with what was given by the senses. ... It finally turns out that one can, after all, not get along without metaphysics."

In summary the reason Einstein so resisted the philosophical implications of quantum theory (the observer alters the observed) was because it puts the cart before the horse, or, more accurately in this context, it puts man's present understanding prior to the world itself. And that world, unlike man's changing views of it, isn't subjected to the whims of current scientific theory. Perhaps this is why Einstein resisted the vast majority of his colleagues who accepted the idea that what quantum mechanics presented was the limits of what could ever be known. Einstein's underlying metaphysic was that science was an attempt to bypass man's limited understanding over time and hence to make an interregnum theory final was to ignore both history and reality.

As Einstein so famously stated, "Quantum theory is certainly imposing. But an inner voice tells me that it is not yet the real thing. Quantum theory says a lot, but does not really bring us any closer to the secret of the Old One. I, at any rate, am convinced that He (God) does not throw dice."

Chapter Three: Bohr Plays Poker

The great extension of our experience in recent years has brought light to the insufficiency of our simple mechanical conceptions and, as a consequence, has shaken the foundation on which the customary interpretation of observation was based.

Physics is to be regarded not so much as the study of something a priori given, but rather as the development of methods of ordering and surveying human experience.

--*Niels Bohr*

Niels Bohr received his Nobel Prize in physics in 1922, a year after Albert Einstein's award in 1921, though both were given their awards at the same ceremony in 1922 in Stockholm. Einstein and Bohr had a deep fondness and respect for each other and while they certainly had their philosophic disagreements over the years, particularly over how to interpret the new physics, their admiration for each other lasted till the end of their lives.

It has been mentioned in several books dealing with the Einstein-Bohr debate that Einstein was more of a realist when it came to science and Bohr was more of an idealist. This description of their differences is too simplistic to be accurate.

Niels Bohr was deeply involved from the very beginning with the revolution which took place in physics during the first quarter or so of the 20th century. Indeed, his early model of the atom, based in part upon Ernest Rutherford's investigations, was an elemental bridge to later quantum theories which eventually made it obsolete.

It was because of Bohr's simple, but predictive, explanation of the spectral lines of the hydrogen atom that significant progress was made in unearthing the inner workings of physical constants at the subatomic realm.

Bohr, unlike Einstein, enjoyed working with a series of devoted students and loved the to and fro of debating the implications of the latest findings in atomic theory.

It has been convincingly argued by Donald Murdoch in his groundbreaking study, *Niel's Bohr's Philosophy of Physics*, that Bohr was less an idealist and more a pragmatist when it came to interpreting the implications of quantum mechanics. What this means is that Bohr tried to let the physics itself lead to its own interpretation and not try to impose upon it his own already made philosophy.

This is best captured in one of his most famous quotes, where Bohr ruminates, "When it comes to atoms, language can be used only as in poetry. The poet, too, is not nearly so concerned with describing facts as with creating images. It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we say about Nature."

What Bohr reveals here is a deep understanding of the very limits of the scientific enterprise and how human investigations of objective phenomena are intimately limited by its own apparatus. This raises a philosophic conundrum which is age-old and is perhaps best articulated by Immanuel Kant.

As the website *Philosophy Pages* illuminates:

According to Kant, it is vital always to distinguish between the distinct realms of phenomena and noumena. Phenomena are the appearances, which constitute the our experience; noumena are the (presumed) things themselves, which constitute reality. All of our synthetic a priori judgments apply only to the phenomenal realm, not the noumenal. (It is only at this level, with respect to what we can experience, that we are justified in imposing the structure of our concepts onto the objects of our knowledge.) Since the thing in itself (Ding an sich) would by definition be entirely independent of our experience of it, we are utterly ignorant of the noumenal realm.

Thus, on Kant's view, the most fundamental laws of nature, like the truths of mathematics, are knowable precisely because they make no effort to describe the world as it really is but rather prescribe the structure of the world as we experience it. By applying the pure forms of sensible intuition and the pure concepts of the understanding, we achieve a systematic view of the phenomenal realm but learn nothing of the noumenal realm. Math and science are certainly true of the phenomena; only metaphysics claims to instruct us about the noumena.

To grapple with quantum indeterminacy, Bohr developed his idea of Complementarity to help explain one of the chief aspects of how nature reveals itself. And because nature is embedded with complementarity, it is nay impossible to exorcise it away from scientific investigations. In fact, Heisenberg's principle of uncertainty is a defining example of how nature is paired and manifests in ways similar to the Taoist notion of Yin and Yang, or in this case, wave and particle.

As the *Wikipedia* entry on *Complementarity* elaborates:

A profound aspect of Complementarity is that it not only applies to measurability or knowability of some property of a physical entity, but more importantly it applies to the limitations of that physical entity's very manifestation of the property in the physical world. All properties of physical entities exist only in pairs, which Bohr described as complementary or conjugate pairs (-which are also Fourier transform pairs). Physical reality is determined and defined by manifestations of properties which are limited by trade-offs between these complementary pairs. For example, an electron can manifest a greater and greater accuracy of its position only in even trade for a complementary loss in accuracy of manifesting its momentum. This means that there is a limitation on the precision with which an electron can possess (i.e., manifest) position, since an infinitely precise position would dictate that its manifested momentum would be infinitely imprecise, or undefined (i.e., non-manifest or not possessed), which is not possible. The ultimate limitations in precision of property manifestations are quantified by the Heisenberg uncertainty principle and Planck units. Complementarity and Uncertainty dictate that all properties and actions in the physical world are therefore non-deterministic to some degree.

Bohr's overall view dovetails with Ernest Mach's and represents a form of logical positivism. As Jan Faye states,

> Bohr's idea of complementarity thus understood was not so different from Neurath's and Carnap's view of relating all statements about theoretical entities to statements about observable things expressed in terms of protocol sentences. Against Einstein's metaphysical attitude towards a physical reality consisting of things-in-themselves, Bohr could just reply that it does not make sense to operate with a conception of reality other than one which can be described in sentences concerning our empirical knowledge. If experimental knowledge does prohibit an ascription of a precise position and a precise momentum at the same time, it does not make sense to talk about a free, undisturbed electron to have such values anyhow.

It in this sense that Dugald Murdoch sees Bohr's philosophy as pragmatic and not preset. Whereas Einstein would follow his intuition about how nature must or should work, Bohr argued for following the data and letting it determine whatever philosophical course would follow. This is wittingly captured with Bohr's reaction to Einstein's famous dictum that God doesn't play dice when he pronounced, "Einstein, don't tell God what to do."

It can also be that because Bohr worked so closely with those who developed quantum mechanics, specifically his star pupil Heisenberg, that he was more acquainted in a practical way with what worked and what didn't. Bohr got his hands dirty with quantum theory perhaps in a way that Einstein didn't. And due to that was more willing to allow for its radical implications.

As Bohr warned, "Those who are not shocked when they first come across quantum mechanics cannot possibly have understood it."

Bohr became the champion of the single most popular philosophic interpretation of the new physics, which would later be known as the Copenhagen interpretation because of the location of his institute.

In many ways, Bohr's reasoning is akin to what we find in Plato's allegory of the cave, as found in his *Republic*, but with one very telling caveat. In Plato's story we learn that prisoners shackled in the cave cannot actually see the light itself which is casting the varying shadows on the wall. And only later when unhinged can they progress from the rudimentary impressions to clearer shapes and outlines until the full luminosity of the light explains more fully how all these images were generated.

In the quantum mechanical world we are in a similar position, since we cannot actually know both the position and the momentum of any single electron, but only its probabilities and even then how we measure such an outcome predetermines its wave or particle manifestation. What the electron is "really" doing nobody knows.

Apparently nobody can know what a single bit of matter is ultimately doing, since even that definition of "bit" of matter is itself a construct, a theoretical map in order to make sense out of one aspect of what appears at such minute levels of matter. What we get when we penetrate the subatomic realm isn't, to quote Kant, the thing in itself, but only what appears visible to our intervening devices. And since we cannot intrude into that realm without some type of instrument (even a single photon cascading off an electron causes a disruption of the assumed virgin state), we don't unlock nature pure and pristine, but as nature reacts to our measuring devices. In other words, we cannot unlock nature as nature, or electron as electron, or matter as matter, since we are invariably altering what we are examining.

We might occasionally acknowledge this interference even at the macroscopic level (sociologists and psychologists are well versed in interpreter's biases in grappling with raw data), but at the quantum level it looms so large and is so evidential that its impact cannot at any instance be ignored.

Heisenberg's principle of uncertainty isn't merely a temporary limit to man's knowledge, according to Bohr, but a fundamental statement about what that knowledge is. It is for this reason that Plato's allegory is instructive, since we are not in the position of the narrator to look objectively upon the cave from the outside and the inside simultaneously. Rather, we are the prisoners in the cave and only from that position can we both induce and deduce what may or may not be ultimately real, but in so doing we are still at the Kantian level of phenomena.

What quantum mechanics revealed was precisely this epistemological impasse and how it plays out in trying to form a picture about reality. Reality we can never know, since that very concept is itself a fiction which implies that we can somehow act as an objective narrator to the entire cosmos, with a 360 degree purview and a level of certainty which implies that we are impartial witnesses to a play with a beginning, middle, and an end.

No, we are literally like the prisoners in Plato's allegory of the cave, limited by our very existence in what can and cannot know. For Bohr this wasn't merely a philosophical extension of his Kierkegaardian leanings, but the very result of what quantum mechanics revealed about our ability to come to grips with nature and how it responds to our introspections. As Bohr put it, "It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we say about Nature."

Or, as Bohr himself discovered,

> For a parallel to the lesson of atomic theory regarding the limited applicability of such customary idealisations, we must in fact turn to quite other branches of science, such as psychology, or even to that kind of epistemological problems with which already thinkers like Buddha and Lao Tsu have been confronted, when trying to harmonize our position as spectators and actors in the great drama of existence Everything we call real is made of things that cannot be regarded as real.

It is little wonder, therefore, that so many eminent scientists have had such ambivalent reactions and feelings to the implications of quantum mechanics. This is epitomized by a close reading of the following quotes garnered from the Quantum World website:

> Quantum mechanics is magic. *Daniel Greenberger.*

> Those who are not shocked when they first come across quantum theory cannot possibly have understood it. *Niels Bohr.*

If you are not completely confused by quantum mechanics, you do not understand it. *John Wheeler.*

It is safe to say that nobody understands quantum mechanics. *Richard Feynman.*

If [quantum theory] is correct, it signifies the end of physics as a science. *Albert Einstein.*

I do not like [quantum mechanics], and I am sorry I ever had anything to do with it. *Erwin Schrödinger.*

Quantum mechanics makes absolutely no sense. *Roger Penrose.*

Chapter Four: The Einstein-Bohr Crapshoot

Whereas Einstein didn't believe in a God that plays dice in the universe, Bohr not only accepted such indeterminacy but pointed out that it was part and parcel of how we understand the world of physics. Interestingly, Bohr not only acknowledged the cosmic crapshoot, but pointed out that such a game was played in the dark and it was only when we shined some light on the proceedings that we could determine its present outcome. Ironically, our very act of illuminating the hidden play fundamentally alters what we unearth.

It is as if God is playing poker in the dark and we cannot see what hand he is holding until we turn on the lights. But that very act of turning on that light can in and of itself change a face card to a number card or vice versa. Nature is like a very fine and delicate Swiss watch with many extraordinarily small and complicated and interlocking pieces hidden behind a silver chamber. We are like a brutish man with very large hands whose fingers lack any finesse or dexterity trying to figure out exactly how that watch works. But every time we try to understand its sophisticated mechanism we invariably mangle its parts by our clumsiness. Thus our very act of trying to understand or fix the watch changes, to some degree, its constituent parts.

It is for this reason that Bohr could say with confidence that we don't see nature as nature, but as nature is revealed to us through our acts of measurement, which may be more accurately described as acts of intrusion.

Both Bohr and Einstein were troubled by the new physics and the decades long discussion/debate they carried on over the implications of quantum theory provides us with one of the great philosophical debates of the 20th century.

Some commentators have outlined the Einstein-Bohr debate into four stages, starting with the Solvay Conference of 1927. Others have suggested that the debate took two major developments. While still others have argued that it was rather just one long debate which evolved over time. Regardless of how the Einstein-Bohr debate is partitioned, it is widely accepted that the discussion got its first fireworks at the Fifth Conference of Physics at Solvay when Einstein strenuously objected to quantum indeterminacy.

Einstein ingenuously came up with thought experiments which tried to show how uncertainty relations could be overcome and thus violate the notion of indeterminacy. At first Einstein's critique was predicated upon a modification of the famous double-slit light experiment, where he suggested that some form of measurement, albeit merely theoretical and infinitesimally small, could indeed be made which would violate the notion of indeterminism.

At first, it looked as if Einstein had provided a penetrating body blow to the new physics, but Niels Bohr brilliantly demonstrated that even in light of Einstein's updated modification it would still be impossible to gather the precision necessary to refute indeterminacy. As one commentator summarized its more technical aspects, "Bohr observes that extremely precise knowledge of any (potential) vertical motion of the screen is an essential presupposition in Einstein's argument. In fact, if its velocity in the direction X before the passage of the particle is not known with a precision substantially greater than that induced by the recoil (that is, if it were already moving vertically with an unknown and greater velocity than that which it derives as a consequence of the contact with the particle), then the determination of its motion after the passage of the particle would not give the information we seek. However, Bohr continues, an extremely precise determination of the velocity of the screen, when one applies the principle of indeterminacy, implies an inevitable imprecision of its position in the direction X. Before the process even begins, the screen would therefore occupy an indeterminate position at least to a certain extent (defined by the formalism."

The problem that was haunting Einstein here was one of measurement, since if he could show (even theoretically) that it was possible to get a precise fix on a quanta event it would violate Heisenberg's principle of uncertainty and show prima facie that realism could be re-introduced into the new physics. In their first formal confrontation over this matter, even despite Einstein's cleverness, Bohr showed conclusively how Einstein's thought experiment was in error.

At the next Solvay Conference, however, held in 1930, Bohr had a much more difficult time overcoming what became infamously known as "Einstein's box." This thought idea is actually fairly straightforward and not difficult, even for us armchair observers, to comprehend.

Again, relating to Heisenberg's principle of uncertainty, Einstein imagined a box which contained a certain limited amount of electromagnetic radiation and which was trapped within a certain small region. Adjacent within the box was a clock which was connected to a small aperture which, given a set time, would release a photon (or small packet of radiation) from within the trapped box, thereby decreasing the amount of energy it originally contained. Connected outside of this box was a weighing scale which allowed for measuring the weight within the box before and after the photon or radiation was released. This would conceivably allow for two differing weights and thus provide one with a certainty hitherto not allowed under uncertainty relations. This thought experiment is based, in part, upon Einstein's famous equation of E=MC2, where matter is literally congealed energy and thus carries weight which is amenable to some form of measurement.

Imagine the weight of Einstein's box with some bundled radiation and imagine the weight of that same box which has released through its portal a quanta of energy. It should be possible, given this scenario (which also contains a clock to accurately provide the time when that photon is released), to gather precise information about such electromagnetic energy that is not allowed under indeterminate coordinates.

In sum, Einstein's box should contradict indeterminism and thus allow for a realistic interpretation (and not merely a probabilistic one) for what transpires at the subatomic realm.

The simplicity of the experiment makes it look at first glance exceedingly convincing. Indeed, it did look to be true, even to Bohr who apparently was flummoxed when he first learned of it.

As Leon Rosenfeld commented, "It was a real shock for Bohr...who, at first, could not think of a solution. For the entire evening he was extremely agitated, and he continued passing from one scientist to another, seeking to persuade them that it could not be the case, that it would have been the end of physics if Einstein were right; but he couldn't come up with any way to resolve the paradox. I will never forget the image of the two antagonists as they left the club: Einstein, with his tall and commanding figure, who walked tranquilly, with a mildly ironic smile, and Bohr who trotted along beside him, full of excitement."

However, Bohr eventually saw the flaw in Einstein's Box, and through a crafty use of reasoning, which ironically employed using Einstein's own great discoveries against himself, he was able to show why the device wouldn't work as predicted.

As one encyclopedia entry on the subject elaborates,

> The "triumph of Bohr" consisted in his demonstrating, once again, that Einstein's subtle argument was not conclusive, but even more so in the way that he arrived at this conclusion by appealing precisely to one of the great ideas of Einstein: the principle of equivalence between gravitational mass and inertial mass. Bohr showed that, in order for Einstein's experiment to function, the box would have to be suspended on a spring in the middle of a gravitational field. In order to obtain a measurement of weight, a pointer would have to be attached to the box which corresponded with the index on a scale. After the release of a photon, weights could be added to the box to restore it to its original position and this would allow us to determine the weight. But in order to return the box to its original position, the box itself would have to be measured. The inevitable uncertainty of the position of the box translates into an uncertainty in the position of the pointer and of the determination of weight and therefore of energy. On the other hand, since the system is immersed in a gravitational field which varies with the position, according to the principle of equivalence the uncertainty in the position of the clock implies an uncertainty with respect to its measurement of time and therefore of the value of the interval Δt. A precise evaluation of this effect leads to the conclusion that the relation cannot be violated.

After the Sixth Physics Conference at Solvay, Einstein took a different line of criticism, since he apparently accepted (at least temporarily) the recalcitrant inherency of uncertainty. Rather, Einstein argued that though quantum mechanics provided much headway into the more esoteric realms of physics, it was nevertheless an incomplete theory. As Einstein explained, "I have the greatest consideration for the goals which are pursued by the physicists of the latest generation which go under the name of quantum mechanics, and I believe that this theory represents a profound level of truth, but I also believe that the restriction to laws of a statistical nature will turn out to be transitory....Without doubt quantum mechanics has grasped an important fragment of the truth and will be a paragon for all future fundamental theories, for the fact that it must be deducible as a limiting case from such foundations, just as electrostatics is deducible from Maxwell's equations of the electromagnetic field or as thermodynamics is deducible from statistical mechanics."

Perhaps the height of the Einstein-Bohr debate happened in 1935 when Einstein, along with Boris Podolsky and Nathan Rosen, published a landmark paper in *Physical Review* under the title, "Can Quantum-Mechanical Descriptions of Physical Reality Be Considered Complete?" This paper, perhaps more than any other Einstein has written, has generated the most heated debate about quantum theory. Because at the time it was written its profound implications were mostly overlooked or prematurely dismissed.

An abstract of the paper which was published in Volume 47, Issue 10 (see pages 777 to 780) of *Physical Review* is deceptively simple:

> In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In quantum mechanics in the case of two physical quantities described by non-commuting operators, the knowledge of one precludes the knowledge of the other. Then either (1) the description of reality given by the wave function in quantum mechanics is not complete or (2) these two quantities cannot have simultaneous reality. Consideration of the problem of making predictions concerning a system on the basis of measurements made on another

system that had previously interacted with it leads to the result that if (1) is false then (2) is also false. One is thus led to conclude that the description of reality as given by a wave function is not complete.

It turns out to be one of the great ironies of this famous paper is that it ended up providing a very strong case for (and not against) quantum mechanics. What the paper sets out to do, more formally, is this (according to *Wikipedia's* entry on *EPR*):

The EPR experiment yields a dichotomy. Either

1. The result of a measurement performed on one part A of a quantum system has a non-local effect on the physical reality of another distant part B, in the sense that quantum mechanics can predict outcomes of some measurements carried out at B; or...
2. Quantum mechanics is incomplete in the sense that some element of physical reality corresponding to B cannot be accounted for by quantum mechanics (that is, some extra variable is needed to account for it.)

At the time that this paper was published, it was not yet known how to "test" its basic hypothesis, and thus it was attacked on more theoretical grounds or as in the case of Wolfgang Pauli discounted without due consideration.

Just months after Einstein's collaborative paper was published in 1935, Bohr published his own rejoinder (with the same title as Einstein's, "Can Quantum Mechanical Description of Physical Reality be Considered Complete") in the same *Physical Review* in Volume 48, Issue 8, pages 696-702. Although Bohr didn't provide an experiential rebuff to Einstein, he did lay out his point by point critique.

Argued Bohr:

Such an argumentation, however, would hardly seem suited to affect the soundness of quantum-mechanical description, which is based on a coherent mathematical formalism covering automatically any procedure of measurement like that indicated. The apparent contradiction in fact discloses only an essential inadequacy of the customary viewpoint of natural philosophy for a rational account of physical phenomena of the type with which we are concerned in quantum mechanics. Indeed, the finite interaction between object and measuring agencies conditioned by the very existence of the quantum of action entails—because of the impossibility of controlling the reaction of the object on the measuring instruments if these are to serve any purpose—the necessity of a final renunciation of the classical ideal of causality and a radical revision of our attitude towards the problem of physical reality. In fact, as we shall see, a criterion of reality like that proposed by the named authors contains—however cautious its formulation may appear—an essential ambiguity when it is applied to the actual problems with which we are here concerned.

To understand what is at stake, it is perhaps important here to introduce the concept of quantum entanglement, where two electrons (each with opposite spins) are forever engaged with each other such that a decisive change of one electron's spin from upward to downward must (because of quanta superposition of two states) change the other twin's electron spin from downward to upward, and vice versa.

A more technical, yet precise, explanation is provided by David Bohm, J. Hilts and others. The following excerpt from an entry on quantum entanglement from the online encyclopedia *Wikipedia* appears based, at least in part, upon J. Hilts' 2007 paper in the *Journal of Physics*.

We have a source that emits pairs of electrons, with one electron sent to destination A, where there is an observer named Alice, and another is sent to destination B, where there is an observer named Bob. According to quantum mechanics, we can arrange our source so that each emitted electron pair occupies a quantum state called a spin singlet. This can be viewed as a quantum superposition of two states, which we call state I and state II. In state I, electron A has spin pointing upward along the z-axis (+z) and electron B has spin pointing downward along the z-axis (-z). In state II, electron A has spin -z and electron B has spin +z. Therefore, it is impossible to associate either electron in the spin singlet with a state of definite spin. The electrons are thus said to be entangled.

Alice now measures the spin along the z-axis. She can obtain one of two possible outcomes: +z or -z. Suppose she gets +z. According to quantum mechanics, the quantum state of the system collapses into state I. (Different interpretations of quantum mechanics have different ways of saying this, but the basic result is the same.) The quantum state determines the probable outcomes of any measurement performed on the system. In this case, if Bob subsequently measures spin along the z-axis, he will obtain -z with 100% probability. Similarly, if Alice gets -z, Bob will get +z.

There is, of course, nothing special about our choice of the z-axis. For instance, suppose that Alice and Bob now decide to measure spin along the x-axis, according to quantum mechanics, the spin singlet state may equally well be expressed as a superposition of spin states pointing in the x direction. We'll call these states Ia and IIa. In state Ia, Alice's electron has spin +x and Bob's electron has spin -x. In state IIa, Alice's electron has spin -x and Bob's electron has spin +x. Therefore, if Alice measures +x, the system collapses into Ia, and Bob will get -x. If Alice measures -x, the system collapses into IIa, and Bob will get +x.

In quantum mechanics, the x-spin and z-spin are "incompatible observables", which means that there is a Heisenberg uncertainty principle operating between them: a quantum state cannot possess a definite value for both variables. Suppose Alice measures the z-spin and obtains +z, so that the quantum state collapses into state I. Now, instead of measuring the z-spin as well, Bob measures the x-spin. According to quantum mechanics, when the system is in state I, Bob's x-spin measurement will have a 50% probability of producing +x and a 50% probability of -x. Furthermore, it is fundamentally impossible to predict which outcome will appear until Bob actually performs the measurement.

So how does Bob's electron know, at the same time, which way to point if Alice decides (based on information unavailable to Bob) to measure x and also how to point if Alice measures z? Using the usual Copenhagen interpretation rules that say the wave function "collapses" at the time of measurement, there must be action at a distance or the electron must know more than it is supposed to. To make the mixed part quantum and part classical descriptions of this experiment local, we have to say that the notebooks (and experimenters) are entangled and have linear combinations of + and – written in them, like Schrödinger's Cat.

As this is a fairly complicated and technical feature in quantum mechanics, varying physicists from Erwin Schrodinger (thus the famous "Schrodinger's cat") to David Bohm, have tried to explicate it by using ordinary objects that we are all familiar with.

To further illustrate what is at stake here and to perhaps underline why quantum mechanics has been described as "weird," imagine that the paired electrons are actually a deeply in love married couple far into the future. After their initial honeymoon, the couple (we will call them Brad and Angelina) have to go back to work on their respective planets (they met on an interstellar dating service over the trans-galaxy web service), which are in completely different solar systems, separated by a billion miles. Since our entangled pair, like their electron counterparts, represent the dynamic fusion of opposing spins (the female/male interplay), further imagine that if Brad was to have a sex change operation and turn himself into a she, his wife, Angelina, must (given this obviously forced analogy) in turn change herself into a "he."

The question that arises here, as it does with paired electrons, is how long would the change take and how would it be implemented? In other words, how would Angelina find out that her lover Brad has become "her" so that she may become "him"? In a conventional physics sense, we are tackling the issue of how information travels and how long it takes to traverse spatial distances. More pointedly, we are coming to grips with the very foundation of modern physics and how matter behaves. At the quantum level, however, we have discovered that things operate quite differently than we ever expected. Given the speed limit that has defined how fast objects can travel (basically the speed of light, 186,000 plus miles per second), we would expect the information about Brad's sex change to reach Angelina in about an hour and a half, give or take a few minutes depending on initial conditions. What we would not expect is for such information to reach Angelina in no time at all.

It was in reaction to this absurd claim (something nonlocal could actually influence a very specific local event) that Einstein used his pithy phrase, "spooky actions at a distance." In his 1935 paper with Podolsky and Rosen, Einstein had no idea at the time that the very objection he was making about quantum theory was in itself the basis for a hypothetical experiment which would decades later actually be performed and show, quite conclusively, that spooky action at a distance (or nonlocal interference) was indeed part and parcel of quantum reality.

Writes Einstein:

> One could object to this conclusion [the one Einstein was making about quantum theory not being complete] on the grounds that our criterion of reality is not sufficiently restrictive. Indeed, one would not arrive at our conclusion if one insisted that two or more physical quantities can be regarded as simultaneous elements of reality only when they can simultaneously measured or predicted. On this point of view, since either one or the other, but not both simultaneously, of the quantities P and Q can be predicted, they are not simultaneously real. This makes the reality of P and Q depend upon the process of measurement carried out on the first system, which does not disturb the second system in any way. No reasonable definition of reality could be expected to permit this.

But this very last quoted line in what is known more commonly as the EPR paper (so named because of the initials of the three authors) is precisely what does happen in quantum entanglement. It is precisely what does happen when Brad gets a sex change operation on a distant planet and becomes a female and Angelina instantly turns into a man, even though she is a billion miles away. Einstein's spooky actions at a distance are right, even if he coined that phrase as a pejorative slight on the utter silliness of the notion.

At the time of this paper, however, there was no way of knowing that it would serve as the impetus for J.S. Bell to devise an experiment to find out if hidden, but local, events were really transpiring at the quantum level or, rather if quantum mechanics was indeed a complete description and something non-local was occurring. As J. Hilts wrote in his review of Einstein and Bohr's 1935 papers:

> With these results [as shown in Bohr's experiment as mentioned in his paper] Bohr claimed that the description of physical reality given by EPR was wrong. Their conclusion regarding the quantum mechanical incompleteness of the description of reality is thus also false.
>
> The conclusions of the EPR paper try to resolve this paradox by stating that quantum mechanics is merely a statistical approximation of a more complete description of nature which has yet to be discovered. In this more complete description of nature there exists variables pertaining to every element of physical reality. There must be, however, some unknown mechanism acting on these variables to give rise to the observed effects of "non-commuting quantum observables." Such a theory is called hidden variable theory.
>
> John S. Bell derived a set of inequalities, known as Bell's Inequalities, which showed that the predications [sic: predictions?] of quantum mechanics through the EPR thought experiment actually differed from the predictions of various hidden variable theories. These predictions have much stronger statistical correlations between measurement results performed on different axes

than the hidden variable theories. These theories are generally non-local; recall the EPR paper used locality as one of their arguments.

Today most physicists believe that the EPR "paradox" is only a paradox because our classical intuitions do not correspond to physical reality in the realm of quantum mechanics.

Although Bohr wrote a fairly lengthy critique of Einstein's position, he didn't know enough at the time of non-local variables to drive home the point that spooky action at a distance is indeed allowed and predicted by quantum theory. Indeed, if non-local influences would have been known then, Einstein couldn't have written, "No reasonable definition of reality could be expected to permit this." Yet five decades later, such a definition of reality (albeit at the quantum level) turned out to be both reasonable and true. As the CNRS website in France explains:

In 1974, Aspect began probing the subject, building upon the pioneering work of John Clauser and collaborators. He understood how to test the locality hypothesis, central in the controversy. He developed polarizers whose settings could be changed every ten nanoseconds and set up a source of entangled photons with an unprecedented efficiency. The key experiments, carried out at Orsay in 1982 by Aspect, Philippe Grangier, Gérard Roger, and Jean Dalibard, showed a clear violation of Bell's inequalities in conditions closely resembling the ideal "Gedanken Experiment"—the foundation for the theoretical discussions. Quantum theory was once again vindicated. "A pair of entangled photons should be considered as a global, inseparable quantum system," Aspect concludes. Twenty years later, it appears this work has helped in launching the second quantum revolution, with promises for quantum cryptography and quantum information processing.

Conclusion: Who Won the Game?

The most interesting feature of the Einstein-Bohr debate is that even though both physicists have been dead for over nearly a half century (Einstein in 1955 and Niels Bohr in 1962), the debate they started in the 1920s is still continuing. Some physicists, such as David Bohm, have championed newer versions of realism where quantum indeterminacy is resolved by introducing such notions as the "pilot-wave" model which allows for reintroducing "actual positions" for particles "without the traditional invocation of a special, and somewhat obscure, status for observation." (The hallmark of the Copenhagen interpretation of quantum theory). As the *Stanford University Encyclopedia on Philosophy* explains:

> Bohmian mechanics, which is also called the de Broglie-Bohm theory, the pilot-wave model, and the causal interpretation of quantum mechanics, is a version of quantum theory discovered by Louis de Broglie in 1927 and rediscovered by David Bohm in 1952. It is the simplest example of what is often called a hidden variables interpretation of quantum mechanics. In Bohmian mechanics a system of particles is described in part by its wave function, evolving, as usual, according to Schrödinger's equation. However, the wave function provides only a partial description of the system. This description is completed by the specification of the actual positions of the particles. The latter evolve according to the "guiding equation," which expresses the velocities of the particles in terms of the wave function. Thus, in Bohmian mechanics the configuration of a system of particles evolves via a deterministic motion choreographed by the wave function. In particular, when a particle is sent into a two-slit apparatus, the slit through which it passes and where it arrives on the photographic plate are completely determined by its initial position and wave function.
>
> Bohmian mechanics inherits and makes explicit the nonlocality implicit in the notion, common to just about all formulations and interpretations of quantum theory, of a wave function on the configuration space of a many-particle system. It accounts for all of the phenomena governed by

nonrelativistic quantum mechanics, from spectral lines and scattering theory to superconductivity, the quantum Hall effect and quantum computing. In particular, the usual measurement postulates of quantum theory, including collapse of the wave function and probabilities given by the absolute square of probability amplitudes, emerge from an analysis of the two equations of motion — Schrödinger's equation and the guiding equation - without the traditional invocation of a special, and somewhat obscure, status for observation.

While still other physicists, such as Hugh Everett, have extended the logical implications of quantum indeterminism and postulated a many worlds hypothesis, whereby "there are myriads of worlds in the Universe in addition to the world we are aware of. In particular, every time a quantum experiment with different outcomes with non-zero probability is performed, all outcomes are obtained, each in a different world, even if we are aware only of the world with the outcome we have seen. In fact, quantum experiments take place everywhere and very often, not just in physics laboratories: even the irregular blinking of an old fluorescent bulb is a quantum experiment."

A growing number of physicists today are taking a fresh look at the philosophical implications of the Einstein-Bohr debate and suggesting that Einstein's objections to quantum theory being incomplete deserves more attention. Others have suggested that the debate can only be resolved by trying to find a grand unified theory which unites gravity with electromagnetism. Philosophically, the issue of realism in physics versus statistical approximations is a profound one and has implications for fields ranging from evolutionary psychology to Bayesian probability theories in neuroscience.

As for an ultimate winner of the Einstein-Bohr debate, it may well be that the answer to that question is as indeterminate as the position of a single photon.

Recommended Readings

Annotated Books on Quantum Theory

While researching the material for this monograph, *Spooky Physics*, I read several very helpful books in the field of quantum theory. These works including biographies of Albert Einstein, Niels Bohr, Erwin Schrodinger, and Max Born, as well as books on the topic of quantum physics itself. The following offers an annotated biography of just a few of my sources:

The End of the Certain World *by Nancy Greenspan*

This biography of the life and times of Max Born was such a pleasure to read that I found myself a bit saddened upon its closure. It left me wanting to read even more on the life of this great physicist. Born, who inspired the world with his plea for ethical standards in science and his call to break through some of the great mysteries of the universe, was a hero of sorts. He was a man of character, tolerance and brilliance. His deep friendships with Einstein and Bohr and other renowned scientists showed the human connections he made while developing deep insight into the world of the atom.

While nurturing tight bonds with other scientists, Born's relationship with his wife, Heidi, was quite unusual. He tolerated her dalliances, especially with her eight year lover, Herglotz. Despite Heidi's romantic adventures, Born loved her and wanted to maintain a married life with her. Heidi is not necessarily an unlikable character herself. She is strong willed and insightful, and in times when Max needed direction she was there. Heidi's brief interest in Vedanta philosophy, developed while living for a stint in India, was replaced with her calling to Quaker social ideals. She remained his wife until Max's death in 1970. And when she dies two years after her husband, she was buried next to him.

It was not until the latter years of Born's life that he received the Nobel Prize in physics. For many years Max felt slighted for not receiving the prestigious award when others in his field did. Even many of the students he worked with, including Heisenberg and Pauli, were honored. But finally towards the end of his life this special award came his way. A knock on the door by a Swedish journalist announcing the news was the climax of his life. Walking down the isle, although nearly tripping in front of the king of Sweden, to receive this honor was the affirmation he so long for. On his gravesite in Gottingen, Germany reads his groundbreaking equation in quantum mechanics: pq-qp = h/2pii.

While Born's contribution to physics is undeniable, he himself questioned his own status in the field. When Oppenheimer omitted him when listing the great theoretical physicists of his time, Born, who once taught Oppenheimer, wrote him a letter expressing his hurt and anger. Oppenheimer's response was that he simplified the list to reduce confusion but he clearly acknowledged Born's work as the very foundation of quantum theory.

Max Born was a natural humanitarian and pacifist in similar vein with Einstein. When other scientists wanted to use their research skills for weapons research Max argued for strict ethical guidelines in science. "Love," he said, "is a power just a strong as the atom." Having to confront the Nazi world as a German Jew, though a non-religious one, was a life altering experience. Many of Max's friends and relatives were killed by the Third Reich. The stress of life during WWII took its toll on both Max and Heidi. Max suffered from bouts of illness, including severe asthma, and Heidi, who suffered from depression and exhaustion, lived months at a time in retreats.

The big debate between Einstein and Bohr about the nature of quantum mechanics was touched upon many times in this reading and was indeed the focus of my attention. Born, while extremely respectful to Einstein, argued against Einstein's position of a deterministic world, going as far as to call him "wrong." Bohr's uncertain world of quantum mechanics, though counterintuitive, he thought was an accurate understanding of nature. The "end of the certain world" is an appropriate title to grasp Born's position.

I found it interesting that the author garnered her research with the help of Olivia Newton-John, the granddaughter of Max Born. Altogether this was a remarkable read.

Niels Bohr's Times, in Physics, Philosophy, and Polity *by Abraham Paris*

The author Abraham Paris, who was good friends with Bohr, offers a brilliant biography of this scientific genius and philosopher. Bohr (died 1962 at 77 years old of heart failure) is credited with founding quantum theory. His great insight was that quantum theory violated the classic concepts of physics held sacred. Bohr's correspondence principle was his attempt to reconcile the new and old physics together.

Taking Paris' lead, let us look at Bohr's politics, philosophy and, most importantly, contribution to physics.

Polity:

Bohr sought an open dialogue between the West and USSR so as to prevent what everyone thought was an inevitable cold war. While his dream of openness did not come to fruition, his gallant effort in pursuit of it deserves recognition. Meeting with both Churchhill and Roosevelt to promote an open world and writing several letters to the United Nations in the 1950s on the topic resulted it little change toward post-war peace. During WWII, Bohr played a role, though minor, in the weapons program. The fear back then was that the Germans were in the race to develop atomic weapons of mass destruction. Bohr later argued that new atomic weapons could help improve international relationships as each country, armed with devastating weaponry, would take each other very seriously. Bohr wanted Russia to be consulted by Western leaders about nuclear arms in order to prevent a post-war cold war. His noble efforts went unheeded.

During WWII, Bohr helped aid refugees. He himself was under the threat of arrest by the German military police in Copenhagen and so took refuge in England. In Denmark Bohr was considered a national hero for his philanthropy and genius. He also founded the world's leading center for theoretical physics in Copenhagen and this brought world recognition to the city and country.

Philosophy:

Apart from science Bohr held many other interests. He loved art and was well read in Shakespeare and in literature classics. Philosophy was certainly among his fortes.

Abraham Paris placed Bohr as one of the most notable "twentieth century philosophers." His complementarity concept applied not just to physics but to a variety of areas, including philosophy, psychology, biology and anthropology. The complementarity idea refers to "two aspects of a description that are mutually exclusive yet both necessary for a full understanding of what is to be described." This sort of reminds me of F. Scott Fitzgerald who said that the sign of an intelligent mind is the ability to hold two totally contradictory ideas at the same time and still function. While Bohr's initial concept applied to physics, specifically the idea that quanta is both wave and particle, he contended that we should take this idea of complementarity and apply it to other fields of study. Paris comments that for him the complementary way of thinking was "liberating." Interestingly, Einstein, who showed great love for Bohr, never came around to accept Bohr's way of thinking here. Einstein, instead, argued that when we look deeper we will one day see that phenomena existed independently of observation as supported by classical physics.

Moreover, in terms of philosophy, Bohr read Kierkegaard's works not just for philosophical insights (note: though baptized in the Lutheran Church, Bohr was a non religious man; he paralleled Einstein who was a non-religious figure as well), but also in admiration of his style of writing. Bohr's own philosophy seemed to parallel Kant's, specifically Kant's view that causality was not derived from experience but was an a priori judgment.

Apparently Bohr even demonstrated some interest in Eastern philosophy when he chose the Chinese symbol Yin-Yang as his emblem on his coat of arms when knighted in Denmark. This fit with his complementarity concept that opposites are indeed complementary.

Physics:

Besides being considered the grandfather of nuclear medicine, Bohr is most known for being one of the key founders of quantum theory of matter. The indeterminism of quantum mechanics did not fit with the causal rules of classic physics. This Bohr full heartedly embraced along with the "epistemological lessons" it taught us, while Einstein argued that a correct understanding of quantum mechanics that reconciled old physics with the new was yet to be discovered.

Paris explains that quantum theory can be broken up into two time periods: 1900 to 1925 referred to as old quantum theory in which the science of quantum theory was established and analogies were used to understand atomic orbits; the second phase began after 1925 with the onset of quantum mechanics. Heisenberg, Born, Schrodinger, as well as Bohr, etc., mark this latter phase. Bohr's significant contributions to quantum mechanics began in 1927. While Heisenberg discovered the uncertainty principle around this time, Bohr developed the complementarity principle. This principle offers us not only a scientific understanding of wave-particle duality but also a deep philosophical insight into life.

While Einstein eventually accepted quantum mechanics, he continued to argue, unlike Bohr, that a deeper theory will one day explain what appeared to be a dichotomy between classic physics and quantum physics. Bohr's position did not waver, despite hours of intellectual debate between Einstein and Bohr. Bohr contended that no deeper theory need explain the difference between physics of the very small (quantum) and Newtonian physics. For some reason, quipped Bohr, the laws of physics break down when we went the weird world of quantum mechanics.

Thus began the famous debate between Einstein and Bohr which still has not officially been resolved. And it is not simply a physics debate but indeed a profound philosophical one as well.

A Short History of Nearly Everything *by Bill Bryson*

This book begins with the origins of the universe 13.7 billion years ago and then continues throughout to cover many of the major scientific advances and historical events that have made the earth that we live in today. The understanding of the atom, the discovery of the DNA structure, the extraordinary advancements we have made in geology, astronomy, anthropology are all subjects of this amazing book. If one wishes to learn a variety of scientific ideas in one read this is it. How does one cover a short history of nearly everything? Well, while this is a very difficult task, Bryson certain succeeds in familiarizing the reader with the life of Newton, Darwin, Einstein, Crick, etc., and the great advancements they each made.

Certain sections of this book caught my attention more than others. I will focus on what captured my imagination, specifically, concentrating on the sense of wonder that science undoubtedly invokes.

Andrea Diem-Lane

Astronomy:

The awesomeness of our universe is a central point in the book. It is fascinating to note that at least 90% of the universe is dark matter, that which we cannot even see, and thus empty space is really not empty at all. Moreover, strangely the universe is expanding out at an accelerated rate. Scientists can actually prove that the universe is expanding by looking at what is called as "the red shift." As light moves away from us we see the red end of the light spectrum and blue as light approaches us. Through the telescope we witness red.

The Big Bang is a topic of great importance in this book. Bryson points out that one percent of the static on the TV is from the Big Bang, a moment of singularity. Perhaps we are in an eternal cycle of collapsing and expanding universes and that ours is just one of many larger universes. Physicists argue that there may be not just one universe but an infinite number of them. And ours might have no end as it folds back upon itself like a bubble ("boundless but finite").

Proxima Centauri is our nearest star and is part of a three star cluster called the Alpha Centauri. This nearest star is 100 million times farther than the moon and 4.3 light years away or 25,000 years by spacecraft. The next star would be Sirius, another 4.6 light years away. Bryson really tries to get the reader to appreciate how enormous outer space is where the "average distance between stars is 20 million million miles."

In terms of statistics, there are most likely other life forms out there but it is unrealistic, even the great distances, that we have encountered them. There are at least 100 to 400 billion stars in our Milky Way Galaxy and at least 140 billion galaxies out there. "If galaxies were frozen peas there would be enough to fill a large auditorium," states Bryson. Interestingly, he says that a conservative number puts advanced civilizations in the Milky Way in the millions. Sagan calculated that the number of possible planets in the universe is "10 billion trillion" and that if you were thrown at random in the universe the chances that you would be next to one is "one is a billion trillion trillion." There is just so much unimaginable space out there.

And thank goodness for the vastness of space given that a Supernova, a star that collapses and then explodes, if nearby would destroy any life on our planet. It was about 4.5 billion years ago an object the size of Mars hit earth and the debris that came from the earth formed within a year into the moon we have today. And how fortunate we are to have this moon, for the moon's gravitational pull keeps the earth stably spinning and not wobbling off.

Bryson continues to show how amazing it is that we have life on this planet. If we were just 5% nearer to the sun or 15% farther from the sun life here could not exist.

Anthropology/Biology:

Bryson also spends a great deal of effort exploring how fascinating the human being is! If one event was a bit off in the 3.8 billion years of earth's history you would not be here. One nanosecond different and there is no you. Amazing! Humans live on average 650,000 hours, a fleeting amount of time in the cosmic scheme of things. Also, most species only lasts 4 million years and 99.99 percent of all species are now extinct. What a privilege that we are here as we are now.

"Why is our fossil record so thin?" Bryson queries. Well, the chances of being fossilized are very rare. Bryson points out that "only one bone in a billion" become fossils. If this be the case then out of all of the Americans today (270-300 million) with 206 bones each only 50 bones will fossilize (1/4 of a skeleton). And then consider that we will have to find these 50 hidden fossils.

At the cellular level humans are all "youngsters." Most cells live no more than a month, and for cells that stay with you like brain cells (while you have 100 billion of them, you lose 500 of them every hour) individual components of them are also renewed monthly. Amazingly, "there isn't a single bit of us that was part of us nine years ago." Talk about reinventing ourselves.

One interesting question that Bryson tackles is: what is the genetic difference between humans? Actually, we are 99.9 % genetically the same. Four simple letters make all the diverse forms of life we see today. One time in a million there is a SNIP, a mutation. The .1% difference is due to our snips. We don't see huge mutations all around us since 97% of our DNA is junk DNA and many snips occur there. Junk DNA is still around in our code since they are good as getting copied but have no detectable consequence.

We have the same number of genes as grass (about 30,000). Sixty percent of our DNA matches that of a fruit fly. What this tells us, explains the author, is that all of life is one. Think of the awesome reality of this. Four little letters make up the ingredients for all life forms on this planet. We are all intimately connected at the deepest levels.

In this book, the author investigates our most recent ancestors. Homo erectus, it appears, is an important dividing line. Before Homo erectus the Homo species looked apelike and after looked humanlike. Early modern humans appeared to move out of Africa about 100,000 years ago. Neanderthals existed for about 100,000 years as well but died out about 35,000 years ago. It seems that there is no genetic connection between mitochondrial DNA of modern humans and Neanderthals. It is still a mystery why they died out. Perhaps we competed for the same resources, Bryson ponders. Humans have existed for only .0001% of Earth's history and in celebration, Bryson exclaims, what an "achievement" it is that we are here.

Physics:

The section on physics is called a NEW AGE DAWNS. Here one learns about the beginning of the quantum age. Energy, according to Planck, can come in individual packets called quanta. It is really "liberated matter" as Einstein's E = MC2 indicates. Moreover, space and time are now understood not to be absolute but relative to the one observing. The faster you go the slower time goes. Even stranger, time is part of space and is known as the dimension spacetime. Gravity can bend spacetime and warp it. Mass of any kind alters the 'fabric of the cosmos." The universe can be described as the "ultimate sagging mattress." Gravity now gets re-thought. Instead of a force it is "the byproduct of the warping of spacetime." As one physicists said, "What moves the planets and stars is the distortion of space and time."

While the Greeks first proposed atoms, it was Einstein who provided solid evidence for their existence with his 1905 paper on Brownian motion. Atoms are composed of three sections: electrons, protons and neutrons (the latter two are in the nucleus). Interestingly, "if the atom were expanded to the size of a cathedral, the nucleus" (the atom's mass; incredibly dense but only one millionth of a billionth of the total atom) "would be about the size of a fly but many thousands of times heavier than the cathedral." Most of the atom is empty space and "solidity" is really an illusion. Bryson continues: "When you sit in a chair, you are not actually sitting there, but levitating about it at a height of one angstrom (a hundred millionth of a centimeter); your electrons and its electrons implacably opposed to any closer intimacy."

The atoms that make you up are from the original stardust of the universe. Bryson points out that they have been "part of millions of organisms on the way to becoming you." Indeed, our atoms are recycled at death. At least one billion of our own atoms came from Shakespeare and from Buddha and from all the other historical greats. It takes decades for the atoms to be "redistributed." But they do go on, indefinitely, and into any variety of forms. Thus, we are reincarnated in a way.

In the world of the very small the same laws that govern the macro world do not apply. The idea of quantum leaps (an electron could leap from one place to another without visiting the space between) won Bohr the Nobel Prize in 1922. Strangely, the electron, showing a dual nature, sometimes acted like a wave and sometimes like a particle. Heisenberg captured this with the Uncertainty Principle. When observing an electron we can know either the position of an electron or its momentum or pathway but not both. We cannot know or predict where an electron will be but only make a probabilistic assumption. The quantum world even gets stranger with Wolfgang Pauli's Exclusion Principle. Atomic particles can have pairs and when separated they can know what each other are doing. A sister particle will spin to match its twin at the same rate but opposite direction, even if trillions of miles away. Einstein referred to this as "spooking action at a distance," and was bothered that something could outrace the speed of light. Einstein, while contributing a great deal to this field, also had a problem with the notion that quantum world is one of indeterminacy. "God does not play dice," he asserted. Einstein hoped to discover a theory (the Grand

Unified Theory) to explain both the world of the very small and the very large. Having two sets of laws in the universe did not make sense to him.

Superstring Theory was also mentioned in this text. At the level of the smallest of the small what was thought of as particles (quarks, leptons) are now understood as vibrating strands or strings of energy that "oscillate in 11 dimensions." Throughout this work Bryson hoped to titillate our imagination and show how science reveals a world of mystery and awesomeness and there is no doubt that he succeeds in this attempt. Does he explain everything? Well, "nearly everything." What a pleasure to read!

Challenging Nature *by Lee M. Silver*

Lee Silver makes an interesting case that nature is raw, cruel and what the author calls a "nasty mother." An example of the harshness of nature occurred 240 million years ago when almost 95% of all species were wiped out. There is no loving Mother Nature making sure everything works in perfect harmony. It just does not care.

Humanity, on the other hand, does care. So why not pursue techniques, as offered by biotechnology (such as stem cell research), to lessen the blows Nature gives. Eastern cultures tend to fit with this way of thinking more than Western traditions. In the West, there generally is the idea that we are "playing god" when we interfere with Mother Nature. But in the East, where there is no "master plan on the universe," such play with nature is viewed as acceptable. Silver petitions the West to reconsider its stance and to embrace biotechnology and all its benefits. In other words, we should "challenge nature" by utilizing such technology to create a brighter future for all.

Science has so much to offer us. Certainly, we are not at the "end of science" as John Horgan has argued. Instead, science is an ever evolving and enlightening disciple with numerous insights and technologies yet to be had. At the very least it has allowed us to "extricate ourselves from the grip of natural selection."

In the book a section called "Spirits" investigates just how deep and widespread religious beliefs are in the West. There are at least 10,000 different religions worldwide and within Christianity there are about 34,000 Christian denominations. In America 90 plus percent believe in God and about 50% support creationism. Fundamentalism is evidently on the rise. Unfortunately, science is feared by many since their religions offer a contrarian view.

A scientific understanding of the world can be traced back to Aristotle and Democritus with their materialist perspectives. Physicalism, says Silver, is actually the more correct term than materialism since immaterial, massless particles (e.g., photons) needs to be included.

One of my favorite ideas in the book was Silver's explanation how evolution and quantum physics relate. Evolution is driven by random mutations. But how do mutations occur? Most mutations, he explains, are caused by "a high energy cosmic ray (quantum particles) that knocks a single atom of the DNA molecule out of place." This was indeed a brilliant connection between two prominent fields in modern day science. It reminds me of Edward O. Wilson's consilience theory where one field such as physics directly interconnects with another such as biology.

30,000 to 50,000 years ago when the religious mind arose in human culture. Perhaps Karl Marx was wrong when he suggested that religion would naturally go away in a just society. Instead, religion could be an innate evolutionary mutation encoded within our DNA but at varying levels. The power of genes keeps religion in play.

One question remains: if the origins of religions can be described as a genetic mutation in the course of human history then why was this mutation naturally selected in the first place? Silver suggests spirituality arose out of an awareness and fear of death. Concepts of life after death relieved anxiety and thus we lived a happier life. As this genetic propensity for spirituality continued, it became amplified with each generation and became the norm. The bottom line: religion was a product of evolution and genetically based. The author calls the genes "spirit genes." And, interestingly, an overdose of them could result in psychosis. Prior to the 1990s scientists viewed religion as a byproduct of culture and not genes. But today the evidence shows otherwise.

Another very interesting section of the book was when the author compares humans with chimps. The 1% difference between us ends up being genes of little significance. We are almost genetic twins with the chimp. Can we produce offspring hybrids together, queries Silver? Most likely, but it would require that the human female carry the fetus and not the chimp (a chimp could not carry such a large offspring full term). Obviously, huge ethical considerations prevent this experiment.

Silver continues to explain that five millions years ago a common ancestor gave rise to humans, chimps and bonobos (pygmy chimps). And as recently as 30,000 years ago we competed with another homo species, Neanderthals, for resources.

More remarkable, 18,000 years ago there is evidence of Homo erectus in Indonesia. Homo sapiens probably are responsible for both of their demise.

Why did we develop consciousness as we have it and other creatures like chimps did not? Most likely, Silver says, to "out-compete or kill off cousins who were not equally endowed." How did this mutation occur? As Silver states, "a mutation can be induced by a single cosmic ray that breaks apart a chemical bond between two DNA atoms" and that occurs instantaneously and randomly. The mutation that allowed humans to develop language (and one can argue a form of sophisticated consciousness) is the gene FOXP2. This gene is lacking in the non-human world.

The genome of humans is a subject that receives a lot of attention in this text. Silver clarifies that each human cell contains two sets of about "30,000 genes stored in 46 chromosomes." The genome is all the genetic information within each cell in the human body. While every cell has the same genome, a liver cell, for instance, has the liver portion active within it.

Overall, this was a fascinating book that I highly recommend. Silver's thesis that we need to "challenge nature" (primarily since nature certainly brutally challenges us) was very insightful and appreciated. More than anything, I was especially inspired about the connection between evolution and quantum mechanics and Wilson's consilience theory coming to life.

Schrodinger: Life and Thought *by Walter Moore*

Walter Moore details the life, science and philosophical bent of the famous physicist, Erwin Schrodinger. An only child, Schrodinger was recognized as brilliant even at the age of three. He was always top in his class and eventually became an amazing physicist and mathematician.

In terms of religion, Schrodinger fits in the atheist camp. He even lost a marriage proposal to his love, Felicie Krauss, not only due to his social status but his lack of religious affiliation. He was known as a freethinker who did not believe in god. But interestingly Schrodinger had a deep connection to Hinduism, Buddhism, and Eastern philosophy in general. Erwin studied numerous books on Eastern thought as well as the Hindu scriptures. He was enthralled with Vedanta thought and connected ideas of oneness and unity of mind with his research on quantum physics, specifically wave mechanics.

Schrodinger was almost as much of a philosopher as he was a scientist. While many Western philosophers fascinated him, including Nietzsche, Kant, etc., Schopenhauer was probably the most significant to him. This philosopher shared with Schrodinger an interest in Buddhism and Vedanta thought, which Schopenhauer called atheistic religions. He went on to describe pantheism as "a euphemism for atheism." And Schopenhauer's view of the struggle for existence and the raw, brutal forces of nature seemed to Erwin to accurately depict reality. Spinoza, Einstein's favorite philosopher, was also of great interest to Erwin.

Schrodinger's marriage to Annie was an unusual one. While they remained married throughout their lives and he died with her at his side, he was not attracted to her physically. Both decided to live a more libertine life and engage in discreet affairs. He fathered a couple of daughters with two mistresses. Annie's lover was Hermann Weyl, a scientist and friend of Schrodinger.

What did Schrodinger contribute to physics? Like Einstein he dreamed of discovering a unified field theory but neither scientist were successful there. Instead, Schrodinger made his name in physics and won the Noble Prize for wave mechanics (a wave equation for particles). He was also noted for matrix mechanisms.

Einstein Defiant: Genius vs. Genius in the Quantum *Revolution by Edmund B. Bolles*

While offering a rough outline of Einstein's life, Edmund Bolles focuses on Einstein's resistance to the implications of quantum theory. Einstein did not think that the quantum world was fully understood and that a complete theory was yet to be had. He held faith in the idea that "the universe makes sense and runs on meaningful physical law." The indeterminism of the quantum world did not sit well with Einstein and hence his famous quote, "God does not play dice with the universe." Along the same thought, he expressed, "The Lord is...not malicious." Underlying the indeterminacy of quantum physics, he argued, was an ordered and predictable reality one day to be discovered. The "secret of the Old One," an objectively ordered and comprehensible world, was there to be found. Einstein eventually stood alone in this position; he remained defiant throughout his life. An inner voice, he said, told him that quantum mechanics is "not yet the real thing."

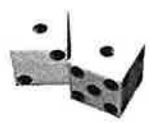
The other genius to counter Einstein was Niels Bohr. Both physicists highly respected and admired each other but could not see eye to eye on this most pivotal research. Bohr, coming from the Copenhagen school of thought, embraced the radical insights of "lawless chaos" and "statistical randomness" quantum theory posed. Causality and meaningful law fell apart at the quantum level, quipped Bohr. The "quantum jump," where a particle leaps from one location to another without following a predicable trajectory or without going through the space in between, was an example of this. Like Bohr, Max Born posited that underneath all the apparent natural laws was only "chaos."

Heisenberg's uncertainty principle accepted by Bohr and Born stated that one cannot know the position and momentum of a particle since they are "exclusive notions." We are left with only probabilistic and statistical interpretations, according to Born. Thus, reality, as classical physics portrayed, now longer fit. Nonetheless, the "correspondence principle" allowed Bohr to use classical ideas to solve modern quantum problems. The bottom line: classical physics did not need to be rejected argued Bohr.

Both geniuses, Einstein and Bohr, also disagreed on the topic of light quanta. Einstein was amazed by the duality of light. His hv refers to the particle-wave duality of light quantum (later knows as photons or even wave packets). Bohr, along with some other physicists, resisted the hv theory but to some degree later came around when the evidence warranted it. "Wavy little chunks of hv" were eventually deemed to be real as the Compton Effect showed.

There is one more area that highlighted the difference between these two thinkers. Einstein loved his philosophers. Just like Erwin Schrodinger, one of his favorites was Schopenhauer. He would study them for entertainment. Bohr, on the other hand, referred to philosophy as "pure drivel."

This book served an excellent read demonstrating how Bohr's "poetic attitude" and Einstein's "realistic" one set the stage for one of the most fascinating debates in the history of physics. And this debate still continues today capturing the attention of scientists around the world.



About the Author

Andrea Diem-Lane is a tenured Professor of Philosophy at Mt. San Antonio College, where she has been teaching since 1991. She received her Ph.D. and M.A. in Religious Studies from the University of California, Santa Barbara. Dr. Diem earned her B.A. in Psychology from the University of California, San Diego, where she conducted original research in neuroscience on visual perception on behalf of V.S. Ramachandran, the world famous neurologist and cognitive scientist.

Professor Diem has published several scholarly books and articles, including *The Gnostic Mystery* and *When Gods Decay*. She is married to Dr. David Lane, with whom she has two children, Shaun-Michael and Kelly-Joseph.